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THE RELATIVE NUTRITIVE EFFICIENCY OF CERTAIN CALCIUM COMPOUNDS WITH GROWING SWINE[1]

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The insistent demands of the producer have always been for greater and more economical production. So with changing times, rations, which formerly seemed adequate because rate of growth and feed requirements in the semi-wild state are of minor importance, now require special supplementation in order to procure optimum gains under the present, rather artificial conditions. Among the necessary nutritional elements, calcium is considered to occupy a prominent place and, like the other nutritional factors, seems to be demanded in greater quantity by the animal body under the present system of handling livestock. The non-toxic calcium salts and the organically derived calcium compounds are used to a considerable extent in animal nutrition as calcium supplements. In fact, calcium in these forms is regarded by many progressive feeders as a necessary component in their animal rations.

Some of the common sources of mineral calcium are: limestone, the high calcium grade; bone meal; calcium carbonate; tri-calcium phosphate; and calcium sulphate. This latter compound is a relatively new source of calcium for animal feeding, an important source being from bones in the manufacture of phosphoric acid.

Although in a general way each of these compounds seems to supply a sufficiency of the needed element, it is quite possible, however, that there is a best single or combined source of calcium for farm animal rations. In this treatise it is proposed to nutritively evaluate the several calcium compounds and combinations of them, using the results of swine feeding experiments conducted during the winter of 1927-28 at the Iowa Agricultural Experiment Station.

REVIEW OF LITERATURE

SOURCES AND COMPOUNDS

The function of calcium in the body has been studied in perhaps greater detail than most of the other mineral elements. Since calcium is one of the principal components of the skeletal structure and seems necessary in other physiological processes, it was surmised, and rightly so, that calcium was an essential element in nutrition.

In the pure state calcium is a white metal quite similar in color to silver. It can be cut with a knife or fractured by a blow, the fracture

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being crystalline. The metal melts at 810°C. and has a density of 1.548. Commercial calcium, however, is usually coated with calcium chloride, which can be partly removed by absolute alcohol and totally by melting in an iron bomb. In this way a metal containing 99.44 percent calcium is obtained; Thorpe (*33*).

Of the common compounds of calcium, the oxide, lime, is perhaps the best known. Calcium in this form has long been employed in the preparation of mortar. Another universal form is the carbonate which in the impure state is found as calc-spar, marble and limestone. The double carbonate of calcium and magnesium, termed dolmite, constitutes the geological formation named dolmite rock or magnesium limestone. According to Thorpe (*34*): "The purest dolmites are the snow white crystalline dolmite marbles of the Swiss Alps, Norway, etc., which have sometimes the character of a statuary marble and can be used for ornamental purposes." Calcium is also the base of a great number of natural silicates, some of the commoner compounds being wollastonite, okenite and xonalite. The phosphate of calcium when united with the chloride or fluoride occurs in other rock formations as apatite. The sulphate of calcium is a plentiful and widely distributed compound. It is found in the anhydrous form in some limestone rocks and mixed with common salt as the mineral anhydrite. However, it occurs hydrated more frequently as gypsum ($CaSO_4.2H_2O$), of which selenite, satin-spar and alabaster represent different forms of crystallization. The soluble matter carried away by rivers consists largely of the carbonate and the sulphate, while sea water contains in addition both the phosphate and the fluoride of calcium.

FUNCTION IN NUTRITION

The shells of molluscs contain quite a considerable proportion of calcium, principally calcium carbonate. The bones of animals consist for the most part of calcium phosphate with a smaller percentage of calcium carbonate. Except for very small amounts of magnesium, calcium is the only cation capable of forming difficultly soluble salts with the common anions present in biological forms, namely carbonates and phosphates. So calcium alone must carry the burden of furnishing the organism with its framework of ossified tissue which we call the skeleton. It is estimated that calcium phosphate comprises about 85 per cent of the mineral matter of normal bone, and in adult men, according to Sherman, (*22, 23*) calcium furnishes about 1.5 per cent of the total body weight, 99 per cent of which is present in the bones and teeth and the remaining one per cent is present as an essential constituent of the soft tissues and body fluids.

The body tissues and fluids seem dependent upon the presence of calcium salts for their optimum function. According to the present day theories of blood coagulation, calcium is a necessary component for its successful accomplishment. Thus with present knowledge of blood coagulation, a liberal supply of calcium in the blood would be advantageous, when the clotting ability of the blood seems so directly dependent upon a sufficiency of it.

Even the automaticity of the heart seems to be partially dependent upon the presence of calcium in the blood stream. According to Smith (*26*) the three salts, sodium chloride, potassium chloride and calcium chloride, when mixed in a definite proportion will not only keep a frog's heart beating for days but will also resuscitate a mammalian heart which has been apparently dead for some days. The calcium in the blood seems to affect the tonicity and contractions of the heart, for the addition of a calcium salt to the solution which was being transfused through an isolated heart not only brought on contractions but increased the length of time during which they were continued. On the other hand, potassium and sodium seem to be connected with the relaxations of the heart, and inasmuch as the heart beat is composed of alternate contractions and relaxations the normal function seems to be definitely dependent upon a definite proportion of these three elements in the blood stream.

LARGE CALCIUM REQUIREMENTS

While calcium appears to be necessary in the diet at all times for the optimum functioning of the body, there are three periods of life when an especially generous supply is absolutely essential. These periods are growth, pregnancy and lactation.

Growth

The growth period, compared with maturity, throws a double requirement on the nutritive functions of the animal. New tissues and bone are being rapidly formed which call for large amounts of organic and mineral feeds—that is, larger amounts in proportion than are needed by the mature animal for the repair and reconstruction of waste tissue. The growing skeletal structure, or what is commonly known as osseous tissue, requires a large available source of mineral feeds. Therefore, during growth large amounts of bone forming products should be included in the ration, or lacking them, the animal will suffer and growth will be subnormal or lacking.

Pregnancy

The added requirement of pregnancy for bone forming products seems to vary with different classes of livestock. When a fetus is born in a very mature form there seems to be a considerable drain on the mother during pregnancy for bone forming material. On the other hand, if the fetus is born in a helpless immature state, the demand for minerals upon the mother during the pregnancy period does not appear to be very great. Macomber (*16*), studying the effect of the lack of calcium on rats, found that the females even on very deficient diets produced normal offspring. However, he went on to explain that the possible reason for this might be because the skeleton of the rat fetus is largely cartilaginous, and that there would not be the same relative drain on the mother for the production of fetal osseous tissue as in the case of larger mammals where the young are born with a well developed skeleton. It was found that on the low calcium diets the percentage of intra-uterine mortality was increased above normal, in fact he noted cases where the animal entirely absorbed the fetus. In conclusion, he expressed the opinion that preg-

nancy in rats makes only small demands for calcium above that required for the body functions of the female herself, but he noted that on calcium deficient diets the females looked old, their coats were rough and their gait was peculiar and slow.

Calcium and phosphorus additions to a basal farm mixture for swine, fed during a gestation period, are thought to have no appreciable effects on the size or calcium content of the skeleton of the fetus. Hart and associates (*9*), feeding calcium in the forms of calcium carbonate, tri-calcium phosphate and alfalfa in the rations of pregnant sows, found that there were no appreciable differences in the skeletons of the young, and even in comparisons of high and low calcium rations there seemed to be no effect from a low calcium ration during a single generation on the size or calcium content of the fetus.

Lactation

However, during lactation, Macomber (*16*) found that the need of a larger supply of calcium was essential. He found that the mother rat would lose calcium from her body to supply the need of her growing offspring. There was a limit, however, to the depletion of her body stores, and when this was reached the young showed the lack of calcium by a stunted condition, weakness and often death.

Forbes (*6*) discussing the mineral metabolism of the cow emphasizes that the act of parturition turns loose a pent-up flood of nutriment which has been stored for the use of the calf. This outpouring of mineral rich foods proceeds in a large measure independently of the food supply. Thus pregnancy should not be a period for maintaining the mineral balance and especially the calcium balance in equilibrium, but should be utilized as an opportunity to build up stores of calcium in the body in preparation for the lactation period. Regarding the relative importance of the different mineral elements present in the body, Forbes stated that his investigation made it plain that calcium, because of the large amount present in both the body and milk, and because of the definite characteristics of its compounds, occupies a key position in mineral nutrition.

FACTORS AFFECTING CALCIUM METABOLISM

In order to measure the increase or decrease in the calcium balance in the body, many detailed experiments have been carried out. It is generally believed that the absorption of calcium takes place only in the small intestine and elimination only through the kidneys and the large intestine. A difficulty arose, however, that in measuring the intake and excretion of fecal and urinary calcium, a true picture of the quantity of calcium metabolized in the body is not given. The quite apparent reason for this is that no check has been kept of the calcium which may have been absorbed in the small intestine and later, after it had performed its biological function, perhaps is eliminated by way of the large intestine and so became a part of the total calcium outgo in the feces. Therefore, to correctly evaluate the mineral metabolism, the balance experiment was devised. The animal to undergo mineral experimentation is kept in the metabolism pen or cage for a preliminary test in which values of normal intake and excretion are obtained. Then in the experimental feeding

period, the different values obtained are compared with the normal figures and so differences due to the ration fed can be calculated.

Telfer (*32*), studying the effect of calcium in the ration of dogs and rats, found that on a low calcium diet the calcium absorption in dogs was low even although phosphorus was present in the ration and its absorption by the animal may have increased the absorption of the sub-minimum calcium in the ration. The dogs kept on the calcium deficient diets came down with rickets or developed osteoporosis, but an addition of calcium to the diet effected an increased fixation of calcium in the skeleton. In studying the absorption of both calcium and phosphorus, he was led to believe that both are made soluble by the action of the acid gastric juice and are precipitated in the intestine when the contents become alkaline. The absorption of calcium and phosphorus must, therefore, occur high up in the intestine before the intestinal juices have had time to make the contents from the stomach entirely alkaline. Evidently some phosphorus could be absorbed in an alkaline medium, for he believed some inorganic phosphorus might be absorbed further on in the intestine even after the intestinal contents were normally alkaline. The author concludes that it is improbable that phosphorus deficiencies occur in many normal diets, nevertheless unless sufficient calcium is also present in the diet and is properly absorbed it is unlikely that phosphorus can be fixed in the skeleton.

Meigs (*18*) of the United States Department of Agriculture reports a nutritional deficiency of calcium which occurred at the Government Farm at Beltsville, Md. His observations of low lime rations on lactating cows are especially interesting. On a deficient calcium ration there were no immediate apparent symptoms of a mineral deficiency. The milk yields continued fairly well, the cows' appetites were good and they seemed to thrive and get fat in spite of the low calcium ration. However, a deleterious effect is plainly seen when their milk yield is compared with a group of check animals receiving a higher calcium ration. After being three months on a calcium deficient ration, these cows were giving about 70 per cent as much milk as the cows on the check ration which were producing at a rate about equal to that at the beginning of the experiment. A second calcium deficiency symptom was revealed in reproduction. Although the cows came in heat regularly and were bred at each heat period, only one normal calf was produced from the first mating, the others either failing to conceive or having an abortion of the fetus. Thus the lack of calcium in the diet seemed to produce sub-normal fertility. However, it might be unjust to call it actual sterility, for as Reynolds and Macomber (*20*) point out:

"The application of the term sterility to most, or all infertile matings has led to much confusion of thought. In most of them, the failure of reproduction is, in fact, the result of decreased fertility rather than of actual sterility on the part of the two individuals concerned."

Vitamin D

In the early history of the vitamins, the fat soluble vitamin A was considered responsible for the deposition of calcium in the body. Hart and associates (*10*), in conducting some cattle feeding experiments, found

that there was a factor in green oats and green grass which affected calcium assimilation in the same way as the factor in cod liver oil. Then later Steenbock and others (*29*), using cod liver oil from which vitamin A had been removed, found that it still promoted calcium assimilation in pups and white leghorn chickens. They went so far as to suggest that there was in cod liver oil an antirachitic vitamin as an entity, distinct from fat soluble vitamin A. They did not, however, conclusively prove the existence of another vitamin.

McCollum and Simmonds (*17*), working on the same problem, found that oxidation will destroy vitamin A, but on oxidation of cod liver oil there was a substance present which would prevent rickets and permit normal calcium deposition in the skeleton. Their researches are considered conclusive proof that vitamin A and D are two separate entities. Therefore, it is now accepted as proved that normal calcium metabolism is not dependent upon vitamin A but upon vitamin D assimilation. However, the question is not entirely settled for some believe that the oil, which has always been associated with the effective vitamin, may have some important influence on the intestinal tract. Hart and others (*11*), working on this problem, fed some lactating goats the non-saponifiable fraction of cod liver oil, which included the vitamins, in capsules and also dissolved in corn oil to note any possible variation in calcium assimilation. In the capsule form no beneficial effects were noted, but when this same material was dissolved in corn oil there was a marked improvement in the calcium balance of the lactating animals.

Ultra-Violet Rays

The natural craving of animals for sunlight should have been taken as indicative of its necessity for the optimum well-being of all forms of animal life under natural conditions. It is now definitely proven that sunlight, besides its warmth giving effect, has in its shorter rays—the counterpart of ultra-violet light—some unknown nutritional effect which seems particularly valuable in the metabolism of calcium and phosphorus.

Shipley, Park, Powers, McCollum and Simmonds (*24*), combining the resources of three departments of Johns Hopkins and Yale Universities, studied the value of sunlight on rats. Their animals, which were fed a rickets producing ration but exposed to sunlight, not only did not develop rickets but even became sexually active. The control animals kept in a shaded room showed all the gross and microscopic symptoms of rickets including fractures of the shafts and enlargements of the wrists, ankles, knees and at the ends of all the long bones. As stated before the rats exposed to sunlight showed none of these symptoms. Although the sunshine prevented the development of rickets, it did not entirely compensate for the deficiency of minerals in the diet, either as regards growth and development of the rat as a whole or in the development of its skeleton. In concluding their report, the authors emphasize that neither cod liver oil, sunlight nor ultra-violet light meets the defects in the composition of the diet directly by supplying the body with either calcium or phosphorus but indirectly by so raising the potential of cellular activity so as to secure the most efficient utilization of the available calcium and phosphorus in the ration.

Steenbock and associates (*31*) found, too, that sunlight might be a limiting factor in some specific districts. In experimenting with young growing pigs, their data indicate that sunlight in the absence of a sufficiency of the antirachitic vitamin is an important factor in efficient swine production. They conclude that in swine production in northern latitudes sunlight may be an important factor, especially when the animals are kept under confined conditions.

Ultra-violet light produced by electrical means appears to have similar prophylactic and therapeutic effects common to sunlight. The nutritional value of ultra-violet light was demonstrated by Evvard and associates (*5*) in the production of fall pigs. Feeding a ration of shelled corn, tankage and simple "backbone" minerals, the average daily gain was practically the same both with and without the addition of ultra-violet light irradiation. However, the irradiated pigs saved 35 pounds of feed per 100 pounds of gain. This saving was effected by giving the pigs an average daily irradiation of 17 minutes.

After studying the calcification in rabbits, Mellanby and Killock (*19*) believe that the degree of abnormal calcification is related to the growth of the animal. That is, if a certain amount of a diet produces rickets, double that quantity of the same diet would, because of the increased growth, produce worse rickets. They state that calcification in rabbits quickly responds, as in other animals, to an increase of the calcifying vitamin in the diet or exposure of the animal or feed to ultra-violet light irradiation.

Favorable results with ultra-violet light irradiation are also noted by Steenbock and Black (*27*). Rations irradiated with ultra violet rays from a quartz mercury vapor lamp were found to be as effective in promoting growth and the calcification of bones as when the rats themselves were irradiated.

Phosphorus Metabolism.

The metabolism of phosphorus may sound like an unrelated subject, but nevertheless it seems to be associated with calcium metabolism. In fact, the metabolism of calcium and phosphorus seem to be very closely identified and somewhat interdependent. In a study of the calcium and phosphorus balances in swine, Hart and associates (*9*) found that a large amount of phosphorus already absorbed was excreted in the urine when a calcium free diet was fed. Upon the addition of calcium carbonate some calcium was retained in the body while the phosphorus was stored in increased amounts and practically disappeared from the urine. When both calcium and phosphorus in the form of tri-calcium phosphate were added to the corn ration there was an increased retention of both. They conclude that their work corroborates previously observed data that the addition of calcium carbonate and tri-calcium phosphate increases the production of skeletal tissues. For additional proof they cite an extreme case where the skeletal weight of a 75 pound pig fed tri-calcium phosphate was nearly as great as that of a 146 pound control pig.

Magnesium Metabolism

The metabolism of calcium and magnesium seem to be closely related in the animal body. This is apparently true in spite of the fact that calcium is quite abundant in the body and magnesium exists only in small proportions. Bogert and McKittrick (*4*) experimented on four young women to determine if the calcium intake would affect the urinary and fecal excretion of magnesium and vice versa. They found that an addition of magnesium to the diet as magnesium citrate, in all cases, increased the total excretion of both calcium and magnesium. The former is to be expected, however. It is also logical to conclude that magnesium may substitute for some of the calcium required in the body since the authors note that some magnesium was retained by the experimental subjects. When the converse experiment was undertaken, that is—the increase of calcium in the diet by the addition of calcium lactate, results were not quite so pronounced although they followed the trend of the former experiment. In this case, too, the total calcium excreted in all cases was increased, and in two out of the four subjects there was also an increased excretion of magnesium.

Evidence indicates that calcium may be absorbed in the upper part of the small intestine but still not necessarily stored in the animal body. Bergeim (*1*) fed rats a rachitic diet and when rickets were induced supplemented the diet of some with cod liver oil and others with corn oil. When the rickets were halted in the former, both groups were analyzed and both showed a considerable degree of calcium absorption in the small intestine. It was therefore considered that rickets was not due to a failure of the animal to absorb calcium but rather a failure to utilize it properly in the body. With the addition of cod liver oil the phosphorus eliminated into the upper intestinal tract was absorbed in the lower intestines to produce an ultimate positive balance of this element. In the rachitic animal the calcium absorbed in the upper intestine was excreted in the lower intestine, thus leading to a negative calcium balance. Coincident with this marked excretion of calcium in the lower intestine there was a failure of the phosphorus to be adequately reabsorbed and hence a loss of the latter from the body. This tends to substantiate an earlier deduction of this paper, namely—that phosphorus is generally present in the diet in sufficient amounts but unless there is an optimum absorption of calcium, phosphorus absorption is seemingly below normal and can only be remedied by inducing an increased retention of calcium.

Food Intake

Another important factor is the effect of the food intake on calcium metabolism. By foods we think of their physical action rather than as chemical carriers of vitamins and minerals. Sjollema (*25*) studied the effect of bulky foods on calcium metabolism. He experimented with rabbits using straw and sawdust to increase the fibre content of the rations. When a diet high in calcium and high in fibre was fed he found that there was a very large outgo of calcium in the feces and that the calcium balance was lowered. Apparently, in ordinary health there is a minimum per cent of calcium which must be excreted in the feces. Thus with a high fibre

content ration, there was necessarily a large secretion of feces and in order to maintain a fairly consistent fecal content of calcium the body was depleted of the mineral, or in Sjollema's words, "It was apparently easier to excrete calcium from the bones than to produce feces with a low calcium content."

Roe and Kahn (*21*) recently reported a study of the absorption of calcium from the intestinal tract of human subjects, in which they administered varying doses of calcium lactate to medical students with and without other food. They advanced the observation that there was a lower absorption of calcium when the salt was mixed with other food. However, they do not necessarily wish to infer that the calcium in food combinations is not readily absorbed but merely to state that in the ingestion of calcium salts, the addition of food lowers the quantity of calcium absorbed.

RELATIVE ABSORPTION OF CALCIUM SALTS

The relative absorption of various calcium salts has been studied in detail by several investigators. Irving (*13*), in experiments with dogs under ether anesthesia, injected solutions of various calcium salts directly into the upper part of the small intestine which had been previously tied off immediately below the pyloris. Under these conditions the experimental subjects only survived for a few hours, seven hours being the maximum. Blood samples were drawn half hourly and analyzed to determine the rate of absorption of the calcium salts. Of the four calcium salts used, the calcium in combination with the various anions is absorbed in this order: Acid acetate$>$neutral chloride$>$acid citrate$>$acid lactate.

ACID-BASE BALANCE

Telfer (*32*), in experiments previously referred to, studied the effect of the pH value of the intestine in relation to the absorption of calcium and phosphorus. As already stated, his experiments proved to his satisfaction that calcium and organically combined phosphorus could only be absorbed in an acid medium and consequently were necessarily absorbed in the anterior duodenum before the acidity of the gastric juice had been neutralized. He also found that the addition of acid to the diet increased the absorption of calcium and phosphorus while the addition of alkali had a negative effect.

Several metabolism studies on the acid-base balance with pigs are reported by Lamb and Evvard (*14, 15*). Acid and alkali were fed in swine rations in varying amounts. In moderate quantities, that is, less than 500 cubic centimeters per animal daily, there seemed to be no important negative effects and in one acid feeding trial, there was a slightly increased retention of calcium.

Calcium metabolism on acid and base forming diets is also reported by Bogert and Kirkpatrick (*3*). In experiments with four humans, the ingestion of base forming diets effects a decrease of urinary calcium, and acid forming diets an increase of urinary calcium. The total calcium excretion was lower on the base forming diet than in preceding check period with

three subjects and about the same in the fourth. They, therefore, concluded that calcium is stored more readily on a basic than on a neutral or an acid forming diet.

CALCIUM IN ANIMAL RATIONS

Because of the variation in calcium requirements during different stages in the animal cycle, rations may be rated as sufficient or deficient depending upon how they meet the needs of each individual problem. With large demands for calcium, the ration must be carefully selected or there can be only one result,—the animal or its offspring must suffer. Certain classes of livestock because of the very nature of their management when they are kept under confined conditions seem to need an added supply of minerals to that which they receive in the organic portion of their feed.

The amount of calcium necessary for growth in pigs varies markedly and is hard to determine biologically; therefore, a definite quantity cannot be recommended as being optimum under all conditions. The source of calcium, its availability to the animal, the type of feed, environmental influences and the physiological idiocyncracies of the animals in question are all factors which determine the amount of calcium necessary for optimum growth. Nevertheless, observations and experimental evidence indicate quite conclusively that most of the home grown concentrate feeds, when fed to pigs as the sole source of calcium, are markedly deficient in that element.

It might be interesting at this time to mention some of the more important calcium compounds which are used in nutrition as supplements to home grown feeds. The common organically derived compounds are: bone meal, spent bone black, calcium sulphate (bone derived), calcium lactate and wood ashes. Some of the inorganic compounds are: limestone, calcium sulphate (gypsum), calcium carbonate, tri-calcium phosphate, calcium chloride and rock phosphate. The last mentioned compound may have some toxic effect due to its fluorine content, especially when used in more than a small percentage of the mineral supplement. The calcium sulphate, from the organic source mentioned above, is a by-product in the commercial preparation of phosphoric acid from bones. According to Thorpe (*35*) orthophosphoric acid is prepared commercially from bone ash by digesting three parts of the ash with three parts of crude sulphuric acid (1.55) and 18 or 20 parts of water for two or three days. The solution which contains the phosphorus as calcium tetrahydric diphosphate (superphosphate of lime) is then filtered through linen filters. The orthophosphoric acid is prepared from the filtrate and the precipitate is that form of calcium sulphate which we wish to analyze biologically, a problem of importance in so far as the experimental work of this thesis is concerned.

Steenbock and others (*30*) found that the more common calcium salts, if fed in sufficient quantities, were all absorbed and utilized more or less completely by the animal body. Rats were fed rations containing .3 per cent of calcium in the form of calcium carbonate, calcium lactate, calcium sulphate, tri-calcium phosphate and calcium silicate. Even with

purified rations the calcium requirements of the rats were evidently satisfied inasmuch as the authors state:

"The data bring out conclusively that when calcium is fed in liberal quantities to the rat, the latter can cover its requirements with any of the well known calcium salts. So far as indicated there was no difference in their relative availability. This latter question of comparative availability is, however, still an open question because it is apparent that even the slightest solubility of the most insoluble calcium salt used might still allow the solution of enough calcium if the irrigation of the intestinal contents with digestive secretions is sufficiently large. We have reasons to believe that the total amount of calcium required for normal growth is not near as large as the calcium administered with these various salts."

Another series of experiments was conducted in which the calcium intake was reduced to one-fourth of the amount fed in the above series. Here again sufficient calcium seemed to be present for the animals' needs. Again quoting the authors:

"They (the results) are consistent in revealing no differences in the availability of the calcium salts. We must admit, however, that we are not entirely convinced that slight differences may not exist. . . We do, however, believe that we are entirely justified in concluding that all of these salts are available to a considerable degree as a source of calcium for growth in the animal."

A balance experiment using purebred Poland China barrows is reported by Forbes *et al* (*8*) in which various calcium compounds were compared as to their relative nutritive value. The experiment was run through three ten day balance periods separated by seven day intervals. With additions to a fairly low calcium basal ration made up of corn meal, wheat middlings, linseed oilmeal and common salt, it was found that pulverized limestone, steamed bone flour and precipitated calcium carbonate differed very little in their efficiency to effect an increased retention of calcium. However, in this trial rock phosphate floats compared to the other calcium carrying compounds seemed decidedly the least efficient.

CALCIUM REQUIREMENT

Bethke and Edgington (*2*) report experiments with both rats and pigs to determine the necessary calcium-phosphorus ratio. Calcium and phosphorus were supplied to both rats and pigs in the form of calcium carbonate and sodium phosphate ($NaHPO_4.12H_2O$) respectively using a basal ration of yellow corn, soybean oilmeal and salt. Their work confirmed the opinion that the proportion of calcium to phosphorus in the ration of the rat and pig is an important nutritional factor, especially in determining the amount of antirachitic factor necessary (in this case ultra-violet light irradiation or sunlight). In estimating the calcium and phosphorus requirements of the rat by the relative ash content of the femurs and by a histological examination of the costo-chondral junctions, it was believed that an addition of two parts of calcium phosphate, or using separate sources for calcium and phosphorus, two to three parts of calcium carbonate and three parts of sodium phosphate per 100 parts of the basal mixture, was sufficient to produce normal bone formation.

Metabolism trials to determine the minimum calcium requirements of a pig and a goat are reported by Steenbock and Hart (*28*). A 75 pound pig was fed an initially low calcium ration to which calcium phosphate was added in successively increasing amounts. By determining the intes-

tinal excretion, the optimum amount of calcium to cover the metabolism losses of a mature barren pig was estimated as being equivalent to a daily intake of about .3 gram of CaO per 100 pounds of body weight. The requirements of the mature goat seemed somewhat higher than that of the pig, it being found that a daily intake of .4 to .5 gram of CaO was required per 100 pounds of body weight.

Hart and associates (*12*) found that on good summer feeding, including grain, green grass and silage, insufficient calcium was supplied in the feed of cows giving 45 to 60 pounds of milk daily. However, when one-half pound of calcium carbonate was fed daily per animal a calcium equilibrium was reached and positive calcium balances were restored, irrespective of whether the cows had access or not to direct sunlight. In conclusion they recommend that rations of high producing milking cows on summer pasture should be supplemented with some calcium carrier.

Among other sources of calcium supplements are dairy products and packing house by-products. These include skim milk, buttermilk and the meat by-products. These are very often the more common calcium supplements used on the farm because they supply, as well as minerals, a rich source of animal protein to supplement home grown feeds. Forbes and associates (*7*) found that a ration of corn, wheat middlings, linseed oilmeal, soybeans, wheat bran and rice polish was unsatisfactory as a source of calcium for growing swine, and that rations composed of these feeds would not maintain normal growth of bone. However, when milk and meat meal were added to the ration nine to ten times as much calcium was stored as when an entire grain ration was used.

Experimental Procedure with Results and Interpretations

OBJECTS OF EXPERIMENT

This experiment with swine was conducted to determine the following:

1. The relative value of limestone and calcium sulphate, bone derived, and mixtures of the two in the production of growth.

2. The efficiency of these compounds in the production of gains with a low feed requirement.

3. The effects of feeding calcium sulphate, bone derived, as the sole source of supplemental or added calcium.

4. The place of calcium sulphate, bone derived, in swine mineral rations.

5. The relative efficiency of added calcium fed in combination with phosphorus in form of special bone meal.

DURATION OF EXPERIMENT

This experiment started with the P.M. feed, December 30, 1927. The period covered in this thesis was concluded with the A.M. feed, April 28, 1928, a period of 120 days.

ANIMALS USED

Number and Source. Thirty-five fall pigs, farrowed and raised on the Animal Husbandry Section Farm at Iowa State College, were used in this experiment.

Breeding. The pigs were crossbreds, sired by a purebred Duroc-Jersey boar and out of high grade Poland China sows.

Previous treatment. All the pigs were handled, as nearly as possible, in the same manner before being put on experiment. As soon as the weather permitted after farrowing, the sows with their litters were put out on alfalfa or rape pasture. Their feed consisted of: shelled corn, self-fed; a supplemental mixture of tankage, 70; cottonseed meal, 25; and alfalfa meal, 5; total, 100 pounds, self-fed; and a simple mineral mixture carrying salt, limestone, bone meal and potassium iodide, self-fed.

The pigs were weaned at 60 days, castration being done before weaning and vaccination shortly after weaning. The pigs were fed the same ration after weaning as before except that the supplemental mixture was changed to the following: tankage, 60; cottonseed meal, 20; alfalfa meal, 20; total, 100 pounds, self-fed.

Allotment considerations. In allotment, the thirty-five pigs were divided as equally as possible into seven groups of five pigs each. Among the considerations of allotment were the following: weight, sex, age, breeding, condition and outcome. The allotment was made so that the groups were as nearly as possible the same in all these respects.

HOUSING AND EQUIPMENT

A new building with separate yards, constructed for swine performance record work housed the experimental animals. The inside floor space of each pen was approximately 6′ x 8′, the building being continuous and containing a total of twelve pens. The house was lined with Celotex, a composition board, and a glass substitute, Cel-o-glas, was substituted for windows. This latter although only translucent transmits more of the ultra-violet rays than ordinary window glass. A hinged door in each pen closed the top half of the door space, the lower half being always open. The yard space was approximately 12′ x 8′. The floors of both the house and yards were concrete. This permits easy cleaning and washing and hence better sanitation. The water was given in steel troughs, the supplemental feed in a wooden trough and the shelled corn in self-feeders which were built as a part of the house. The troughs of these self-feeders opened to the inside of the house, but the feeders were filled with grain from the outside.

ALLOTMENT AND RATIONS FED

The composition and allotment of rations during the first 90 days of the experiment were as follows:

Lot I—Check—Shelled corn, mixed, mostly yellow, self-fed, plus "70 per cent protein" Supplement A (Swift's "85 per cent protein" blood meal, 70; "45 per cent protein" peanut meal, 12; "41 per cent protein" cottonseed meal, 5; linseed oilmeal, 5; "22 per cent protein" alfalfa leaf flour, 5; Diamond Crystal salt, flake, 2.998; potassium iodide, C.P., .002; total, 100 pounds) hand fed at rate of .5 pound per pig daily.

Lot II—Limestone, Ground Addition—Fed same as Lot I excepting .5208 pound Supplement B (Supplement A, 96.00; high calcium, ground limestone, 4.00; total, 100 pounds) replaces the .5 pound allowance of Supplement A.

Lot IV—One-half Limestone Calcium (Lot II) Substituted with Calcium from Bone Derived Calcium Sulphate—Fed same as Lot I excepting .5277 pound Supplement D (Supplement A, 94.67; high calcium, ground limestone, 2.00; bone derived calcium sulphate, 3.33; total, 100 pounds) replaces the .5 pound allowance of Supplement A.

Lot V—All of Limestone Calcium (Lot II) Substitiuted with Calcium from Bone Derived Calcium Sulphate—Fed same as Lot I excepting .5356 pound Supplement E (Supplement A, 93.35; bone derived calcium sulphate, 6.65; total, 100 pounds) replaces the .5 pound allowance of Supplement A.

Lot VII—Sodium Sulphate (Anhydrous) Addition to Limestone of Lot II Ration—Fed same as Lot I excepting .5263 pound Supplement C (Supplement A, 95.00; high calcium, ground limestone, 4.00; sodium sulphate, anhydrous, 1.00; total, 100 pounds) replaces the .5 pound allowance of Supplement A.

Lot VIII—One-half Sodium Sulphate (Anhydrous) of Lot VII Replaced by Bone Derived Calcium Sulphate—Fed same as Lot I excepting .5263 pound Supplement II (Supplement A, 95.00; high calcium, ground limestone, 4.00; sodium sulphate, anhydrous, .5; bone derived calcium sulphate, .5; total, 100 pounds) replaces the .5 pound allowance of Supplement A.

Lot IX—All of Limestone Calcium (Lot II) Substituted with Calcium from Special Bone Meal—Fed same as Lot I excepting .5275 pound Supplement I (Supplement A, 94.78; Swift's special bone meal, 5.22; total, 100 pounds) replaces the .5 pound allowance of Supplement A.

During the 30 days period from the 90th to the 120th day of the experiment .2 pound tankage, Swift's "60 per cent protein", per pig daily was added to the above ration, same being mixed with the other supplement and all fed together.

The average daily allowance of each supplemental feed other than tankage for the entire feeding period was as follows:

Supplement and specific minerals fed (average daily per pig).

Lot No. Supplemental Mixture Designation	I A	II B	IV D	V E	VII G	VIII H	IX I
Supplement A	.5000	.5000	.5000	.5000	.5000	.5000	.5000
Limestone	..	.0208	.0106	..	.0210	.0210	..
Calcium Sulphate, Bone Derived	..	..	.0171	.0356	..	.00263	..
Sodium Sulphate, Anhydrous	..	..	..	..	.0053	.00263	..
Special Bone Meal	..	..	..	..	..	..	.0275
Total Supplement	.5000	.5208	.5277	.5356	.5263	.5263	.5275

Other groups which were fed mixtures of limestone and calcium sulphate, bone derived, were not included in this treatise since two pigs of the lots were eliminated from the experiment because of enteritis and one of the remaining members was unthrifty.

Due to enteritis, several of the lots were depleted of one or two pigs during the course of the experiment. All the data reported herein is corrected for these losses. At the close of 120 days of feeding the number of pigs in the various lots was as follows:

	Number of Pigs		Number of Pigs
Lot I	5	Lot VII	3
Lot II	4	Lot VIII	4
Lot IV	4	Lot IX	5
Lot V	5		

Basis for choosing rations. In order to show the effect of the calcium compounds, an adequate basal ration would have been of little value. However, to properly estimate the value of calcium in swine rations the mixture should necessarily be fairly adequate for body growth except for the calcium factor. It was with these thoughts in mind that the basal ration was chosen. The aim in the planning of the experiment was to keep the amount of calcium slightly below optimum. Thus the efficiency of the calcium compounds might be clearly seen in the results.

Blood meal was selected as the principal protein supplement since it contained a high per cent of protein and also a low amount of calcium. The other protein supplements were chosen because they had proven themselves valuable in other feed mixtures. After the experiment had run 90 days it was considered advisable to supplement the ration with .2 pound of tankage per pig daily in order to hasten growth and development.

Feeding. The shelled corn was fed in a self-feeder which operated inside the hog house. The self-feeders were refilled before quite empty and were examined twice daily to be certain that they were feeding properly. The supplemental mixture was hand-fed at about 8.30 A.M. daily.

Watering. The pigs were watered twice daily in open steel troughs. Watering was done at about 8:30 A.M. and 3:30 P.M.

CHEMICAL COMPOSITION OF FEEDS

The chemical analysis of the organic feeds will be found in table 1.

TABLE 1.—*Chemical analysis of organic feeds.**

Feeds Used	Moisture Percent	Dry Matter Percent	Protein Percent	Nitrogen Free Extract Percent	Crude Fibre Percent	Ether Extract Percent	Ash Percent
Shelled corn (14 per cent moisture basis)	14.00	86.00	9.77	69.17	2.43	3.32	1.31
Meat meal tankage	8.28	91.72	58.33	2.50	2.18	8.35	20.36
Blood meal	11.56	88.44	83.63	..	0.50	0.15	4.16
Cottonseed meal	6.26	93.74	41.53	26.03	10.79	8.24	7.15
Linseed oilmeal	9.79	90.21	35.38	31.37	10.12	6.10	7.24
Alfalfa leaf flour	8.87	91.13	21.47	34.15	20.73	3.13	11.65

*Analysis by W. G. Gaessler and J. A. Schulz, Chemistry Section.

ANALYSIS FOR CHEMICAL CONSTITUENTS

An analysis for the chemical elements of the feeds is included in table 2.

TABLE 2.—*Analysis of chemical constituents of feeds.**

Feeds Used	Calcium	Phosphorus	Magnesium	Sulphur
Shelled corn (14 per cent moisture basis)	0.013	..	..	..
Meat meal tankage	6.940	3.44	..	..
Blood meal	0.338	..	..	..
Cottonseed meal	0.238	..	..	..
Linseed oilmeal	0.352	..	..	..
Alfalfa leaf flour	1.720	..	..	..
Ground limestone	38.400	..	1.20	..
Calcium sulphate, bone derived	24.480	0.43	0.51	18.24
Bone meal	33.950	14.06	..	..

* Analysis by J. A. Schulz, Chemistry Section.

BODY MEASUREMENTS OF PIGS

The following body measurements were taken at the beginning of the experiment, at the 90th day, and at the 120th day of the experiment.

Measurement	Instrument of Measurement
1. Body length, tail root to ears	Tape
2. Heart girth	Tape
3. Height, shoulder	Standard
4. Chest, width at heart	Standard
5. Chest, depth at heart	Standard
6. Shin, fore, circumference	Tape

OBSERVATIONS AND DATA COLLECTION

Weights of animals. Two individual weights and one group weight of the pigs were taken at the beginning of the experiment. At the end of every 30 day period individual weights were made. At the end of 90 days and at 120 days three day individual weights were taken.

Observations. Farrowing and weaning data were recorded for all experimental pigs. The probable outcome of each pig was recorded at the beginning of experiment and used as a factor in allotment. Records of individual condition were taken at the beginning of the experiment, at the end of 90 days and at the end of 120 days. Records of measurements were also taken at the above mentioned times.

Feed records. The quantity of shelled corn put in self-feeders was recorded at the beginning of the experiment and whenever they were refilled. A weigh-back of corn left in the self-feeders was recorded every 30 days. The amount of supplement fed was recorded by 10 day intervals.

DISCUSSION OF THE EXPERIMENT RESULTS

The minerals fed in this experiment were the only differences between the rations of the different lots, and so through the course of this discussion the lots will be referred to by names which describe the mineral supplements fed.

TABLE 3.—*Feeding and gains record of the pigs.*

Lot	Designation	Average Daily Gain and Final Weight per Pig		Feeds Used	Average Daily Feed Consumption per Pig				Feed Required for 100 Pounds Gain			
		90 day period pounds	120 day period pounds		90 day period		120 day period		90 day period		120 day period	
					pounds	total	pounds	total	pounds	total	pounds	total
I.	Salt check	.83 122	.01 168	Shelled corn Supplement Tankage	2.5006 .5000	3.0006	3.1719 .5000 .0500	3.7219	302 60	362	315 50 4.97	370
II.	Limestone	.94 132	1.14 184	Shelled corn Supplement Tankage	2.9786 .5200	3.4986	3.5158 .5200 .0500	4.0858	318 55	373	309 46 4.39	359
IV.	Limestone-calcium sulphate	1.25 160	1.38 213	Shelled corn Supplement Tankage	3.8258 .5277	4.3535	4.4415 .5320 .0500	5.0235	307 42	349	322 39 3.62	365
V.	Calcium sulphate	.98 135	1.21 192	Shelled corn Supplement Tankage	3.0626 .5360	3.5986	3.8268 .5360 .0500	4.4128	313 55	368	317 44 4.14	365
VII.	Sodium sulphate (Limestone)	1.24 159	1.39 214	Shelled corn Supplement Tankage	4.1796 .5259	4.7055	5.0515 .5261 . 500	5.6276	337 42	379	363 38 3.59	405
VIII.	Sodium sulphate–calci m sulphate (Limestone)	1.12 149	1.31 205	Shelled corn Supplement Tankage	3.5596 .5249	4.0845	4.2846 .5249 .0500	4.8595	317 47	364	326 40 3.81	370
IX.	Bone meal	1.15 151	1.28 201	Shelled corn Supplement Tankage	3.3864 .5280	3.9144	4.0776 .5280 .0500	4.6556	295 46	341	318 41 3.90	363

General data of feeds and gains record. Figures are presented in table 3 which summarize the data collected on daily gains, daily feed consumption, and feed requirements for 100 pounds gain. These points will be discussed separately and then conclusions will be drawn from the combined data. In general, the discussion will center on the data for the 120 day period, but the figures for the 90 day period will be used as corroborative evidence.

The daily gain. All the groups fed a mineral supplement showed superior daily gains to the salt check group. The limestone and calcium sulphate groups were practically equal in average daily gain and well within the range of probable error. However, the limestone-calcium sulphate group, fed a ration containing a 50-50 mixture of the two compounds, made a much higher gain than when either compound was fed alone. In fact, this group showed practically the highest gains of the series, being equalled only by the sodium sulphate group. These two latter groups gained consistently at about the same rate, both for the 90 and the 120 day periods.

With the substitution of calcium sulphate, bone derived, in Lot VIII for sodium sulphate, the gains were somewhat lower than in Lot VII. However, the difference was perhaps within the limits of experimental error and so should not be taken as final but merely indicative of the effect of these minerals. The sodium sulphate—calcium sulphate group was higher in average daily gain than either the limestone or calcium sulphate groups, and so both this Lot, VIII, and Lot VII, the laxative minerals lots, showed up very favorably when compared to the other groups in the experiment.

The bone meal group ranked fourth in average daily gain for the 120 day period. However, since the four highest average daily gains were quite close it is probable that these were all within the limits of error.

The following gives the rank of the lots in average daily gain for the 120 day period.

Rank of Lots in Average Daily Gain

Rank	Lot No.	Designation	Average Daily Gains, Lb.
1	VII	Sodium sulphate (limestone)	1.39
2	IV	Limestone-calcium sulphate	1.38
3	VIII	Sodium sulphate-calcium sulphate (limestone)	1.31
4	IX	Bone meal	1.28
5	V	Calcium sulphate	1.21
6	II	Limestone	1.14
7	I	Salt check	1.01

Average daily feed consumption. All groups in the experiment showed a considerably higher average daily feed consumption during the 120 day period than during the first 90 days. Thus the average daily feed consumption was increased during the last 30 days, and the gains for each period show that the pigs were gaining more quickly at that time.

The average daily feed consumption in the 120 day period is noticed to be in the same order as the average daily gains. Thus gains made by the pigs seem almost to be directly proportional to the feed eaten. This would likely indicate that no toxicity resulted from any of the rations fed.

Feed Required for 100 Pounds Gain

The feed requirements for 100 pounds gain in all lots except one fell within a range of 11 pounds for the 120 day period. Thus the average daily gain, already discussed, shows almost completely the results of the experiment. The lot outside this narrow range in feed requirement for 100 pounds gain was the sodium sulphate group. This lot had a requiré-ment of 405 pounds of feed for 100 pounds of gain, which was much higher than the other groups. However, the average daily gain was considerably higher than in its check group, II, and so it is problematical whether these differences in feed requirement would have been so great if the average daily gains had been equal.

The feed requirements during the 90 day period were not so closely ranged as in the 120 day period. However, in the former the differences were not great and, as in the latter, the sodium sulphate group showed the highest feed requirement for 100 pounds gain. The limestone and calcium sulphate groups were very close in feed requirements, while the group receiving a mixture of the two compounds was quite noticeably lower than either of them. The salt check group produced gains with a fairly low feed requirement; in fact, this group was third lowest in the series. As in the 120 day period, already mentioned, the sodium sulphate group had the highest feed requirement of the series. The sodium sulphate-calcium suphate group had a lower requirement than the sodium sulphate group but were only slightly lower than the limestone and calcium sulphate groups. The bone meal group showed the lowest feed requirements in the series, and so naturally this group is looked upon with favor in the production of the most economical gains.

TABLE 4.—*Calcium consumption.*

Lot	Designation	Daily per Pig		Per 100 Pounds Gain		Per 100 Pounds Feed Consumed	
		90 day period pounds	120 day period pounds	90 day period pounds	120 day period pounds	90 day period pounds	120 day period pounds
I	Salt check	.0022	.0058	.27	.57	.073	.155
II	Limestone	.0102	.0138	1.09	1.21	.292	.337
IV	Limestone-calcium sulphate	.0107	.0144	.86	1.04	.246	.286
V	Calcium sulphate	.0110	.0146	1.12	1.21	.306	.330
VII	Sodium sulphate*	.0105	.0141	.85	1.01	.223	.250
VIII	Sodium sulphate—calcium sulphate*	.0110	.0146	.98	1.11	.270	.300
IX	Bone meal	.0117	.0153	1.02	1.19	.298	.328

* Limestone.

Calcium consumption. The data in table 4 show the calcium consumption per pig daily, for 100 pounds gain and for 100 pounds feed consumption, by 90 and 120 day periods.

During the 120 day period fairly good gains were made in some of the groups when the pigs received approximately .014 to .015 pound of calcium per head daily; but where a little less than .006 pound of calcium was fed in the salt check group the average daily gain was much lower. The increase of the calcium intake had an appreciable effect on the daily gain, as is shown in the superior gains of all of the lots receiving calcium in addition to the basal ration. The salt check, Lot I, not receiving calcium supplementation, gained 1.01 as contrasted with 1.14 to 1.39 pounds per pig daily in the higher calcium lots, II to IX inclusive.

The per cent of calcium in the feed varied because of the consumption of different amounts of shelled corn. This applied to all groups except the salt check lot. The data show that the pigs on calcium supplements received .25 to .35 per cent of calcium in the ration. The salt check group received about .16 per cent of calcium in the ration. This amount was about one-half of that received by the minerals fed lots, and clearly an insufficient amount for optimum growth with a low feed requirement for 100 pounds gain.

TABLE 5.—*Protein consumption.*

Lot	Designation	Daily per Pig		Per 100 Pounds Gain		Per 100 Pounds Feed Consumed	
		90 day period pounds	120 day period pounds	90 day period pounds	120 day period pounds	90 day period pounds	120 day period pounds
I	Salt check	.588	.683	71.16	67.85	19.61	18.35
II	Limestone	.634	.716	67.65	62.88	18.13	17.53
IV	Limestone—calcium sulphate	.717	.810	57.64	58.70	16.48	16.12
V	Calcium sulphate	.643	.747	65.76	61.93	17.88	16.93
VII	Sodium sulphate (Limestone)	.752	.867	60.64	62.29	15.98	15.40
VIII	Sodium sulphate—calcium sulphate (Limestone)	.691	.791	61.46	60.22	16.91	16.27
IX	Bone meal	.676	.773	58.92	60.35	17.28	16.61

Protein consumption. Table 5 shows the protein consumption of the pigs for the 90 and 120 day periods.

These figures are submitted as a help in analyzing the data on gains and feed consumption. The protein consumption is seen to comprise 16 to 20 per cent of the feed consumed during the 90 day period and from 15 to 19 percent of the ration during the 120 day period. The pigs not receiving a calcium addition (Lot I, check) show the highest percentage

TABLE 6.— *Dimensional growth of pigs. Average initial (Dec. 31, 1927), 90 day (Mar. 28, 1928), and 120 day (April 27, 1928) measurements (inches).*

Lot	Designation	Measurements	Length of Body Ears to tail		Heart Girth		Height at Shoulder		Width of Chest		Depth of Chest		Circumference of Foreshin	
			90 day period	120 day period	90 day period	120 day period	90 day period	120 day period	90 day period	120 day period	90 day period	120 day period	90 day period	120 day period
I.	Salt check	Initial	26.16	26.16	24.32	24.32	17.58	17.58	5.86	5.86	8.02	8.02	4.04	4.04
		Final	37.06	41.56	34.62	37.86	20.90	23.16	8.72	9.74	11.60	12.28	5.48	5.78
		Increase	10.90	15.40	10.30	13.54	3.32	5.58	2.86	3.88	3.58	4.26	1.44	1.74
		Percent increase	41.67	58.87	42.35	55.67	18.89	31.74	48.81	66.21	44.64	53.12	35.64	43.07
II.	Limestone	Initial	27.45	27.45	24.28	24.28	18.35	18.35	6.13	6.13	8.03	8.03	4.03	4.03
		Final	38.75	44.35	30.33	40.60	22.40	27.10	8.70	10.25	11.75	13.40	5.38	5.78
		Increase	11.30	16.90	6.05	16.32	4.05	8.75	2.57	4.12	3.72	5.37	1.35	1.75
		Percent increase	41.17	61.57	24.92	67.22	22.07	47.68	41.92	67.21	46.33	66.87	33.50	43.42
IV.	Limestone-calcium Sulphate	Initial	27.83	27.83	24.08	24.08	18.58	18.58	6.20	6.20	8.28	8.28	4.15	4.15
		Final	41.38	47.78	38.93	42.93	23.05	25.25	9.48	10.95	12.45	13.80	5.60	5.83
		Increase	13.55	19.95	14.85	18.85	4.47	6.67	3.28	4.75	4.17	5.52	1.45	1.68
		Percent increase	48.69	71.69	61.67	78.28	24.06	35.90	52.90	76.61	50.36	66.67	34.94	40.48
V.	Calcium sulphate	Initial	26.86	26.86	25.84	25.84	17.90	17.90	6.06	6.06	7.92	7.92	4.08	4.08
		Final	38.88	44.44	31.86	40.18	23.08	24.52	9.28	10.68	12.00	13.42	5.50	5.92
		Increase	12.02	17.58	6.02	14.34	5.18	6.62	3.22	4.62	4.08	5.50	1.42	1.84
		Percent increase	44.75	65.45	23.30	55.50	28.94	36.98	53.14	76.24	51.52	69.44	34.80	45.10
VII.	Sodium sulphate (Limestone)	Initial	26.83	26.83	25.27	25.27	19.47	19.47	6.80	6.80	8.73	8.73	4.20	4.20
		Final	41.30	45.87	39.87	44.43	27.63	25.97	9.93	11.33	13.13	14.37	5.80	5.93
		Increase	14.47	19.04	14.60	19.16	8.16	6.50	3.13	4.53	4.40	5.64	1.60	1.73
		Percent increase	53.93	70.97	57.78	75.82	41.91	33.38	46.03	66.62	50.40	64.60	38.10	41.19
VIII.	Sodium sulphate-calcium sulphate (Limestone)	Initial	26.25	26.25	25.05	25.05	18.90	18.90	6.28	6.28	7.90	7.90	4.00	4.00
		Final	39.95	44.65	36.20	41.18	22.60	25.08	9.40	10.78	12.03	13.30	5.55	5.90
		Increase	13.70	18.40	11.15	16.13	3.70	6.18	3.12	4.50	4.13	5.40	1.55	1.90
		Percent increase	52.19	70.10	44.51	64.39	19.58	32.70	49.68	71.66	52.28	68.35	38.75	47.50
IX.	Bone meal	Initial	25.00	25.00	23.98	23.98	17.72	17.72	6.06	6.06	8.20	8.20	3.98	3.98
		Final	40.10	44.96	35.00	39.66	23.12	25.52	9.18	10.78	12.26	14.10	5.44	5.86
		Increase	15.10	19.96	11.02	15.68	5.40	7.80	3.12	4.72	4.06	5.90	1.46	1.88
		Percent increase	60.40	79.84	45.95	65.39	30.47	44.02	51.49	77.89	49.51	71.95	36.68	47.24

of protein in their ration because they consumed less corn in proportion to the standardized allowance of protein supplement, same for all groups. Hence the high protein supplemental feed was diluted less from the protein standpoint than in the other groups. The fact that Lot I was fed so little calcium explains why they had but little appetite, relatively speaking, for corn; their consumptive ability was lessened because of the calcium deficiency in their feeds. Every lot receiving a calcium supplement produced 100 pounds gain with less protein consumption than when the minerals were omitted in the salt check, Lot I.

Dimensional growth. Table 6 shows the dimensional growth of the pigs for the 90 and 120 day periods. Although the pigs were fed rations containing smaller amounts of minerals during the 90 day period, nevertheless the data seem to show greater variations by lots in both absolute and percentage increase in dimensional growth during the 120 day period.

All the groups having a calcium addition to their ration showed for the 120 day period a greater absolute and percentage increase in length of body, height at shoulder, width of chest, and depth of chest, than the salt check, Lot. I. A similar situation exists for heart girth with one exception, Lot V, which showed a greater absolute growth, the more significant figure, but a less percentage augmentation. The results covering foreshin increase are somewhat variable in character, but the tendency is for the calcium additions to bring about greater development. Judging growth in the various dimensions on the percentage basis, all things considered, the bone meal group surpassed the others, and the calcium fed lots excelled the salt check, Lot I. The absolute growth of pigs receiving limestone and calcium sulphate, 50-50, was somewhat better than when either of these compounds was fed as the only calcium supplement. This was true for length of body, heart girth, width of chest, and depth of chest.

The following table shows the order of greatest average increase, percentage basis, in the different dimensions for the 120 day period.

Lot	Designation	Length of body ears to tail	Heart girth	Height at shoulder	Width of chest	Depth of chest	Circumference of foreshin
I	Salt Check	7	6	7	7	7	5
II	Limestone	6	3	1	5	4	4
IV	Limestone—Calcium Sulphate	2	1	4	2	5	7
V	Calcium Sulphate	5	7	3	3	2	3
VII	Sodium Sulphate (Limestone)	3	2	5	6	6	6
VIII	Sodium Sulphate—Calcium Sulphate (Limestone)	4	5	6	4	3	1
IX	Bone Meal	1	4	2	1	1	2

Summary and Conclusions

The findings of the swine experiment may be summarized as follows:

1. All the calcium compounds fed, including ground high calcium limestone, calcium sulphate, bone derived, and bone meal, seemed to promote good growth in fall pigs.

2. Calcium sulphate, bone derived, was equivalent in feeding value to ground limestone as a source of calcium in the growth of pigs.

3. During the 90 day period when the pigs were on low calcium levels, a 50-50 mixture of ground limestone and calcium sulphate, bone derived, promoted a larger average daily gain and greater feed economy than when either compound was fed alone.

4. The pigs receiving the limestone-calcium sulphate mineral supplement ate more feed per day but made as efficient use of the feed, producing 100 pounds of gain with about the equivalent amount of feed. Considering the greater final weight per pig in this group, the feed economy may be considered greater.

5. Special bone meal proves to be an excellent supplement for swine rations; because of its phosphorus content, it has an obvious advantage over certain other non-phosphate calcium carriers under many conditions of practical feeding.

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THE EFFECT OF ULTRA-VIOLET RADIATION ON THE UREDINIOSPORES OF SOME PHYSIOLOGIC FORMS OF *P. GRAMINIS TRITICI*

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In papers previous to this (*1, 2*) it has been suggested that the darker coloured spores possess more resistance to ultra-violet light than lighter coloured ones. The purpose of this note is to present further evidence that this is correct and to suggest that the pigment in the spore wall exerts a protective function and prevents injury to the cell; broadly, that it is analagous to the protective pigment, melanin, in man.

Source of Light

A quartz mercury-vapour lamp was used. This was the Home Model Alpine Sun Lamp, alternating current equipment, 110 volts, 60 cycle, manufactured by Messrs. "The Hanovia Chemical and Manufacturing Company."

Materials and Methods

The material used in these experiments was placed at my disposal by Dr. Margaret Newton. To her and her colleagues, Dr. T. Johnson and Mr. A. M. Brown, the writer wishes to express his thanks, not only for the material with which they have supplied him in these experiments, but for initiating him into the technique employed in investigating certain rust problems in progress at the laboratory.

Urediniospores from the physiologic forms Nos. 1, 36 and 9 were used and these were irradiated as they floated on 4 c.c.'s of distilled water contained in Syracuse dishes. Spores were irradiated for given periods one foot from the lamp. Twenty-four hours later, with the exception of the last experiment when counting was commenced after ten hours, the germination percentages were estimated by making counts of either 500 or 1000 spores. In the appropriate tables these have been recorded as relative germination percentages. The percentages for the control, that is those plates that were not irradiated, have been raised to 100, and the other readings elevated in proportion.

If a different technique was employed this is stated in the experiment.

Spore Colour of Forms that were used

Newton, Johnson and Brown (*3, 4*), have described colour mutations in *Puccinia graminis tritici* and also the inheritance of colour in certain physiologic forms. It is with these spores of abnormal colour that the experiments deal chiefly.

These workers state that two pigments are present in the urediniospores of *P. graminis tritici*, one, an orange pigment in the cytoplasm, the other a brownish pigment in the spore-wall.

[1]Dr. Dillon Weston, now stationed at the Dominion Rust Research Laboratory, Winnipeg, Manitoba, is on a year's leave of absence from the School of Agriculture, Cambridge, England, being one of the exchange officers. Dr. J. H. Craigie is now stationed for a year at Cambridge.

In certain forms, however, this is not so. For example, they have shown that the orange coloured spores of a selection from physiologic form No. 9 lack the brownish pigment in the spore wall, and that the spores of form No. 36 (greyish-brown) lack the orange pigment in the cytoplasm. Further, they have shown in another selection which they have discovered that there is little or no pigment in either the spore wall or the cytoplasm. Such selections are referred to as white.

Theoretically it would be expected that the forms which contained their pigment in the epispore would be less susceptible to ultra-violet light injury than those in which it was absent. The following experiments will show that this is correct.

Experiments

1. Physiologic forms No. 9 (normal red) and No. 9 (orange) were irradiated as follows.

Three separate plates of both the red and the orange forms were irradiated separately for periods of one hour, one series in water, and the other dry. Six check cultures were maintained, three of either form. The germination percentage was estimated by counting 250 spores in each plate and then making one count of 250 spores at random on the three plates—the total count for one set being a thousand. In making these counts every spore that showed the appearance of a germ tube, however small, was noted as having germinated.

The percentage germination based on this count is given in table 1. The figures in brackets indicate the results that were obtained ten weeks later when the experiment was duplicated. The percentages were estimated in the same way. In this and other experiments the germination percentage is given to the nearest whole number. Percentages below 0.5 are recorded as a trace.

TABLE 1.—*Shows the relative germination percentages obtained when urediniospores of physiologic form No. 9 (red) and No. 9 (orange) were irradiated for a period of an hour.*

Form	How Irradiated	Relative Number of Spores Germinating	
No. 9 Red	Dry	36	(49)
"	In water	9	(6)
"	Not irradiated	100	(100)
No. 9 Orange	Dry	1	(1)
"	In Water	trace	(trace)
"	Not irradiated	100	(100)

These results afford evidence that the orange coloured spore is more easily killed than the normal red spore. They show also that the spores are more easily killed when they are irradiated in water.

2. Spores of physiologic form No. 1, (red, grey, orange, and white selections) were irradiated in the same manner but in water only and for separate periods of thirty and sixty minutes. Ten weeks later the experiment was duplicated; the results then obtained are given in brackets.

In both experiments the percentage germination was estimated on a count of 500 spores made from a single dish of each culture. These results are shown in table 2.

TABLE 2.—*Shows the relative germination percentages when urediniospores of physiologic form No. 1 (red, grey, orange and white selections) were irradiated for a period of 30 and 60 minutes.*

Form	Relative number of spores germinating		
	Irradiated		Non-irradiated
	30 minutes	60 minutes	
No. 1 Red	16 (8)	1 (trace)	100 (100)
No. 1 Grey	14 (5)	4 (3)	100 (100)
No. 1 Orange	Nil (trace)	Nil (Nil)	100 (100)
No. 1 White	1 "	" "	100 (100)

These figures afford evidence that the white and orange forms are more susceptible to ultra-violet light injury than the red and greyish-brown ones.

3. In a somewhat similar experiment when these forms were irradiated for ninety minutes, germination was not observed in any of the cultures. When irradiated for half that period, forty-five minutes, germination was noted in the red and grey cultures but not in the yellow or white. These results are shown in table 3.

TABLE 3.—*Shows the relative germination percentages when urediniospores of form No. 1 (red, grey, orange and white selections) were irradiated for 45 minutes.*

Form	Relative number of spores germinating	
	Irradiated for 45 minutes	Not irradiated
No. 1 Red	1	100
No. 1 Grey	14	100
No. 1 Orange	0	100
No. 1 White	0	100

4. In the next experiment the physiologic forms used were No. 9 orange, No. 1 red, and No. 1 white. Some of these spores were irradiated in water and others while still on the plant. The distance from the lamp was 8 inches and the period of irradiation one hour. The germination figures estimated on counts of 500 spores are shown in table 4.

The orange and white selections are again the most susceptible to injury. In this experiment it is interesting to note that the mortality is less when the spores are irradiated while still on the leaf.

5. This is confirmed by the following experiment. Spores of form No. 36, normal red urediniospores, were irradiated while still on the plant; some were also irradiated in water. The germination percentage estimated on

counts of 500 spores was as follows. Irradiated on plant, 22 per cent; in water, 0 per cent; not irradiated, 100 per cent.

TABLE 4.—*Compares the relative germination percentages of urediniospores when irradiated on the plant and in water.*

Form	How irradiated	Relative number of spores germinating	
		Irradiated 1 hour	Not irradiated
No. 1 Red	In water	1	100
"	On plant	19	
No. 1 White	In water	0	100
"	On plant	0	
No. 9 Orange	In water	0	100
"	On plant	3	

6. The form No. 1 (white, orange, grey, and red selections) were irradiated in water for periods of 15, 30, 45 and 60 minutes and the percentage germination was estimated on counts of 600 spores. These figures are shown in table 5.

TABLE 5.—*Shows the relative germination percentages of urediniospores of form No. 1 (red grey, orange, and white selections) when irradiated for periods of 15, 30, 45 and 60 minutes*

Form	Relative number of spores germinating				
	Minutes irradiated				Non-irradiated
	15	30	45	60	
No. 1 White	1	0	1	0	100
No. 1 Orange	7	9	2	0	100
No. 1 Grey	47	34	6	20	100
No. 1 Red	41	33	12	2	100

7. This experiment was succeeded by one in which the form No. 1 (red, grey, orange and white selections) were irradiated separately for 10 and 20 minute periods. One culture of each was irradiated and the estimate based on counts of 1000 spores. The experiment was duplicated one month later; these estimates are placed in brackets. The figures are shown in table 6.

8. In this experiment form No. 1 (white) and form No. 1 (orange) were compared with form No. 1 (red). Fifteen separate dishes of each culture were irradiated for different periods as shown in table 8. The distance from the lamp was 1 foot and the counts were made between ten and twenty-four hours afterwards. Two hundred and fifty spores were counted on each dish. The controls consisted of fifteen dishes of the yellow, fifteen of the white and thirty of the red form; these were not irradiated. The results are shown in table 7.

TABLE 6.—*Shows the relative germination percentages of urediniospores of form No. 1 (red, grey, orange and white selections) when irradiated for period of 10-20 minutes.*

Form	Relative number of spores germinating		
	Minutes irradiated		Non-irradiated
	10	20	
No. 1 White	4 (9)	0 (0)	100 (100)
No. 1 Orange	8 (5)	3 (3)	100 (100)
No. 1 Grey	43 (47)	24 (5)	100 (100)
No. 1 Red	24 (18)	3 (7)	100 (100)

These figures justify the belief that at least one of the functions of the pigment is to protect the protoplasm of the cell from ultra-violet light injury. They indicate, moreover, that the pigment in the cytoplasm is of little use in this respect. It is the pigment in the cell wall that acts as the protective agent.

It should be stated here that these spores were examined also several days after they were irradiated, and the germination counts did not differ materially from those made twenty-four hours after irradiation. It is assumed that these spores were killed and not rendered dormant.

TABLE 7.—*Shows the relative germination percentages of urediniospores of form No. 1 (red, orange and white selections) when irradiated for 15 periods ranging from 1 to 15 minutes.*

Minutes* irradiated	Relative number of spores germinating			
	Colour selection of form No. 1			
	Red	White	Red	Orange
0	100	100	100	100
1	91	105	113	64
2	104	92	106	45
3	107	55	93	79
4	85	42	104	96
5	68	47	79	106
6	96	25	73	26
7	74	22	73	17
8	71	29	54	6
9	73	16	68	6
10	74	18	51	9
11	76	14	—	9
12	26	9	46	4
13	22	1	56	1
14	31	3	42	2
15	29	8	—	2

* In this experiment the 15 plates were irradiated together, and at one minute intervals the appropriate plates were removed. Consequently, the intensity of the light would vary somewhat on the different plates since the light would strike them at slightly different angles.

9. Spores of *Erysiphe graminis* were irradiated in a similar manner and it was found that they were very susceptible to ultra-violet light injury. For example, when irradiated for 10 minutes one foot from the lamp the

percentage germination was 0.4; this compared with 15 for the non-irradiated. Another series reacted similarly, the percentage germination of the non-irradiated then being 15, and the highest figure obtained for dishes irradiated separately for five, ten and fifteen minute periods was one per cent.

These spores, therefore, react very similarly to the white and orange urediniospores in their susceptibility to ultra-violet light.

In reviewing the germination percentages of the control dishes—those which were not irradiated—it will be noticed that the figures are not always constant. The same selection of the same form differs in germination not only on different days but even when the experiment is carried out on the same day. It is well known that the germination of rust spores is influenced by certain meteorological conditions. But, apart from these, it is thought that there are several other factors concerned. For example, it was noted that the greater the number of spores in a plate the higher was the germination. Conversely, the fewer the spores present the lower the germination.[2]

In interpreting these results another difficulty may be encountered. In table 7 it is seen that ten minutes irradiation of the normal red urediniospores of form No. 1 gave a germination of 74 per cent falling after a further two minutes to 26 per cent; and yet in the previous table (table 6), it was shown that after a ten minute irradiation the germination was 24 per cent. The question will be asked, "Why is there such a discrepancy in results?" It may well be that some of these spores shielded the others, that some were protected slightly by clustering to the side of the plate, and that some dishes contained a greater number of spores than others.

If, however, these results are regarded either in part, or as a whole, such discrepancies will not alter the fact that the white and orange forms relative to the red and grey forms are more susceptible to ultra-violet light injury.

It is thought that the evidence is sufficient for it to be stated that the white and orange urediniospores are killed more easily than either the red or the grey. The obvious inference is that this must be so because these white and orange types have no pigment in the spore wall. The red and grey forms, however, possess such a pigment.

In conclusion the writer wishes to make the following acknowledgements. By the courtesy of the Ministry of Agriculture and Fisheries, England; the Department of Agriculture, Canada; and the financial assistance of the Empire Marketing Board, he has been enabled to exchange from the University of Cambridge, England, with Dr. J. H. Craigie of the Dominion Rust Research Laboratory, Winnipeg, Canada. He wishes to thank those responsible for this transfer.

Summary

1. Urediniospores are killed more easily when irradiated in water than they are when irradiated dry.

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[2]In the foregoing experiments the action of visible white light on the germination of these spores has not been taken into account. In recent experiments, however, the writer has discovered that visible white light exerts a profound action on germination.

2. The spores of the white and orange selections of certain physiologic forms of *P. graminis tritici* are more susceptible to ultra-violet light injury than are the red and grey urediniospores.

3. The spores of *Erysiphe graminis* are as susceptible to ultra-violet light injury as the white and orange urediniospores.

4. It is inferred that the pigment in the spore walls protects the protoplasm of the cells from ultra-violet light injury.

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RELATIVE SUSCEPTIBILITY OF WHEAT VARIETIES TO WIREWORM DAMAGE [1]

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It is well known that among the standard field crops grown on the prairies some are more susceptible to wireworm damage than are others.

Our own experiments in this connection indicate that spring wheat is the most severely attacked field crop. Oats and flax, although both may suffer severely in badly infested fields, are the most resistant, while barley occupies an intermediate position. Fall wheat and rye are about as susceptible as is spring wheat, but damage is usually less evident to these crops since the maximum wireworm feeding occurs in the spring.

These observations have been made in connection with the feeding habits of the Northern Grain Wireworm (*Ludius aeripennis*), which is the most prevalent species in the grain fields of Alberta.

We had not anticipated that there would be an appreciable difference in the susceptibility to damage among the different varieties of wheat. In 1926 we received a letter from Mr. W. D. Albright, Superintendent of the Dominion Experimental Station at Beaverlodge, in which he stated that Garnet wheat appeared to be suffering more heavily from wireworm depredations than did Marquis. He came to this conclusion as a result of observations made upon "dates of seeding" plots in which both varieties were grown under identical conditions.

Certain areas of the land that was devoted to these experiments were known to be badly infested with wireworms whereas others were practically free from them. There was little difference between the yield of these varieties in the wireworm-free plots, whereas in those that were infested that of Garnet was remarkably inferior to Marquis. A survey of infested fields in the neighbouring district appeared to confirm this conclusion. It should, however, be stated here that the difference in yield was far more marked in certain years than it was in others.

In 1927, with the assistance of Mr. H. A. MacGregor, we conducted a series of experiments in order to determine whether we could demonstrate any feeding preference by wireworms for any particular variety of wheat.

Three varieties were selected for experiment; namely Marquis, Garnet and Ruby.

Initial laboratory experiments were conducted with germinated and ungerminated grains in soil filled 8 oz. cans and glass sealers. In certain of these wireworms were offered a number of grains of each variety in order to ascertain whether any one of them was eaten to a greater extent than the others. In other series the wireworms were given the grains of all three varieties in order that a preference for any one variety might be more definitely observed.

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1 This investigation was conducted with the aid of a grant from the National Research Council.
2 Professor of Entomology.

In every experiment we were rather surprised to find that the Marquis grain was eaten rather more extensively than was the Garnet or Ruby. We have no means of reducing this difference in feeding to a figure that would indicate comparative destruction of the grain since some seeds were wholly consumed while others were barely attacked.

Field cage experiments were divided into two classes. In the first we employed galvanized iron cylinders, 6 inches in diameter and 12 inches long. These were sunk into the soil until 2 inches projected above the surface. They were then filled with earth to the level of the surrounding ground. Eight cylinders, in all, were employed. Half of them were seeded with twenty grains of Marquis and the other half with Garnet. Three wireworms, that were identical in size, were then placed into each of the experimental cylinders. The two additional cylinders were reserved as a control and were not infested.

Twelve days later the following observations were made:

Marquis. From 60 seeds, 41 plants were above ground, and all appeared to be healthy.

Garnet. From 60 seeds, 50 plants were above ground, and all appeared to be healthy.

In this experiment plants that were obviously dying were removed each time the cylinders were examined. Since, however, the appetites of the eighteen wireworms employed may not have been identical this type of experiment does not yield very conclusive data. The result, however, coincided with our earlier observations to the effect that Marquis appeared to be eaten more freely than Garnet.

For the second series of field experiments we employed rectangular galvanized field cages that were 18 inches long by 8 inches wide by 10 inches deep. These were let into the soil to a depth of 8 inches and were filled with earth till the level of this was 2 inches below that of the surrounding ground. At this level alternating rows, each consisting of 10 grains of Marquis, Garnet or Ruby were seeded across the short diameter of the cage, which was then filled to ground level.

Six of these cages were employed and the rows of grain were arranged in a different sequence of varieties in each pair of cages. In all cages the end rows were discarded, since they were not entirely comparable with the remainder.

Ten wireworms were introduced into the soil of each cage. We thus had 540 seeds and 60 wireworms under observation.

The cages were examined every other day for the following two weeks. All dead plants were removed and recorded. At the end of this period the surface soil was removed in order that we might ascertain the causes for the failure of any plants to show above ground.

A summary of the observations is as follows:—

Garnet.	30%	seed destroyed before germination.
	38%	plants destroyed after germination.
	68%	Total destruction.

Marquis.	36%	seed destroyed before germination.
	39%	plants destroyed after germination.
	74%	Total destruction.
Ruby.	39%	seed destroyed before germination.
	36%	plants destroyed after germination.
	74%	Total destruction.

Once more it appeared that Garnet was attacked somewhat more sparingly than was either of the other varieties. In this series it should be noted that one might reasonably anticipate an accentuation of any difference in the comparative damage that would occur in grain fields, since the wireworms present had an opportunity to concentrate upon a preferred variety.

In none of the above experiments had any attempt been made to ascertain the relative power of the different varieties to recover from slight damage that did not at the time prove fatal. Although wireworms do not, as a rule, continue to feed to any extent on plants after they have tillered out we noticed that several seedlings had been slightly damaged when we terminated our experiment in order to dig up the seeds. They appeared at that time to be recovering from slight earlier feeding on the stems. In many instances the damage was not apparent above ground and was discovered only when the plant was dug up.

In order to gain some information in this connection we repeated the experiment in 1930 with some modifications. Mr. O. Peck assisted during this summer and he made most of the observations recorded below. The first modification was that Ruby was replaced with Reward since the latter variety is now more extensively grown than is the former. The second was that, instead of terminating the experiment at the end of two weeks, the individual plants were examined frequently till they headed out. The latter modification necessitated the addition of check cages in which the grain could be dug up as soon as it had tillered out and of control cages in which the normal development of wireworm free plants could be observed. Unfortunately a light hailstorm slightly damaged a few of the seedlings thirteen days after the experiment was started. None, however, appeared to suffer permanently. The controls indicated that there was a 100 per cent viability in all varieties though one Reward grain failed to produce a plant.

In the experimental cages the following percentage of grains failed to produce plants:—

Marquis	22 per cent
Reward	20 per cent
Garnet	3 per cent

This indicated surprisingly little feeding upon Garnet grain in comparison with those of other varieties. Even though our earlier experiments had indicated some preference for the others, so great a difference was most unexpected. We would again emphasize the fact that it is in all

probability far more marked than would be the case in a field where one variety only is available.

Despite the excellent start that was made by Garnet over the other varieties in these cages, the subsequent history of the surviving seedlings showed that, by the time of heading out, it suffered far more than did either Marquis or Reward as a result of the presence of wireworms. During the three weeks subsequent to the appearance of the plants above ground a constant succession of Garnet plants wilted and died down. An examination of the check plants indicated that Garnet was not attacked in the seedling stage more heavily than the other varieties but that the attacked plants failed to make any recovery whereas several of those of both Marquis and Reward, though showing signs of damage, managed to survive and ultimately to produce heads.

Of the plants in our experimental cages that showed visible signs of damage above ground the following percentages recovered:—

Marquis	29 per cent
Reward	50 per cent
Garnet	10 per cent

The number of these plants is admittedly small but they indicate the same trend of results as do those recorded below.

In the final analysis, from the seed sown the following percentages of plants died before they headed out:—

Marquis	37 per cent
Reward	32 per cent
Garnet	49 per cent

In addition to the complete destruction of plants, the average number of heads per plant among those that survived was as follows:—

	Controls	Experimental Cages
Marquis	1.1	1.1
Reward	1.5	1.3
Garnet	1.2	0.44

The seed was not sown until June and we were, therefore, not able to mature and weigh the grain produced by each variety. The experiment had, however, fulfilled its purpose in demonstrating that, under certain conditions, Garnet seedlings are less able to withstand the attacks of wireworms than are those of the other varieties of wheat with which we were comparing them.

Field data, collected by Mr. Albright, indicate that the relative reduction in yield between Garnet and Marquis, as a result of rather extensive wireworm feeding on both of them, is more marked in certain years than it is in others. Our experiments, however, support his contention to the effect that it is advisable to seed fields that are known to be heavily infested with wireworms with Marquis or Reward wheat in preference to Garnet.

THE FUNDAMENTALS OF AN AGRICULTURAL RESEARCH PROGRAMME

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In an introductory paper published in *Scientific Agriculture*, July, 1931, we outlined the significance of the "environmental coincidence" in controlling plant growth. As profitable agriculture is dependent primarily upon successful plant growth, as represented by maximum yields at minimum cost, the first concern of research must be the establishment of the definite interrelation of fundamental conditions controlling plant growth in individual areas.

Every plant possesses great potentialities for development of various types of growth. Which of these potentialities shall be developed and which remain dormant is determined by the peculiar environmental coincidence under which the plant is grown. Two varieties of the same plant possessing similar potentialities of behavior, yield, or susceptibility to certain diseases will not necessarily exhibit the same reaction under a given environmental coincidence, for slight variations in breeding usually require corresponding variations in environment for equal development of any given potentiality.

Under present research methods, genetecists and agronomists have been concerned primarily with the individual reactions of different varieties of plants to the particular environmental coincidence under which they happen to be working; but study and comparison of the various reactions of an individual variety to the different coincidences under which it must eventually be grown by the farmers of even one country have been neglected. The chief reason for this concentration on one phase of adaptation is that up to the present individual environmental coincidences occurring in so-called agricultural areas have not been defined. Such comparisons in reactions as have been made have necessarily been confined to the effects of variation in individual factors such as soil, temperature, moisture or cultural methods, upon individual varieties. It has been impossible to consider plant growth in relation to the combination of interactive influences which constitutes any one environmental coincidence because such interrelations have not been established. Consequently, no definite assurance may be given that successful results achieved at one point may be duplicated at another. Results of studies in agronomy, in genetics, and other allied problems, however valuable their individual significance, are merely preliminaries to further costly experiments on the part of individual farmers operating under varying coincidences and subject to the modifications in results which even slight environmental variations may cause.

There is a tendency for the research scientist to feel that when an isolated problem has been solved to his own satisfaction and that of his colleagues his efforts have been justified. *But until these findings have been related to all others which have a bearing on their practical application to the farmers' problems, and until the whole is interpreted in terms*

easily understood by the farmer and extension service, all agricultural research carried out at public expense remains a public liability.

Before such application is possible, however, agricultural research must determine (1) the interrelation of the various environmental factors governing individual types of growth, and (2) the occurrence and distribution of distinct environmental coincidences throughout the agricultural world for purposes of study, comparison, and ultimate economic distribution of crops.

Agricultural Problems Have Become International

Recent agricultural history has definitely established the fact that the maintenance of agricultural stability is an international problem, and that we are sadly under-estimating the possibilities of research when we overlook not only the opportunities but the economic necessity for closer collaboration on agricultural problems of international significance. When agricultural marketing becomes international, problems in costs of production also cease to be local or even national, and must be viewed from the broader perspective of international relationships. In spite of the universal nature of agricultural problems, and in spite of the similarity in occurrence of agro-ecological coincidences throughout different countries, agricultural research has for the most part been carried on with a view to its local rather than its international significance.

Under changing agricultural conditions, however, it is essential that greater facilities be provided for coöperation and exchange of ideas among agricultural research scientists throughout the world. Not only will such collaboration prove economically sound by prevention of duplication and overlapping of research effort, but it will be possible through such coordination to institute a definite programme for complete organization of agricultural research activities.

Necessity for Agricultural Research Programme

Up to the present, the failure of agriculture as an industry to benefit from research in proportion to the achievements of individual agricultural scientists and groups of scientists, has been due to a lack of provision for permanent interrelation of all agricultural investigations and for their ultimate application to practical problems of land utilization and crop distribution. A basic research programme is the only practical solution of our problem of relating the various isolated branches of research, and providing a permanent structure into which may be incorporated the research data accumulated in the past, which will serve as a basis for uniting the scattered efforts of the present, and which will be sufficiently elastic and fundamental to provide for the incorporation of all agricultural research progress of the future. The most pressing needs in agricultural research today are (1) a common goal or objective viewed from the standpoint of the industry as a whole, and (2) a comprehensive programme planned to turn all isolated and hitherto unrelated findings into definite progress towards realization of this objective.

Agricultural research programmes must be primarily provincial or national in character, but their possibilities for broader application must

not be overlooked in outlining any truly basic agricultural policy. That such an outlook is essential to constructive accomplishment on a large scale is apparent to all agriculturists who have considered agricultural problems from the standpoint of their national and permanent significance.

We have in Ontario an agricultural research problem unsurpassed in the world, due to our great variation in latitude, altitude, soil and climate, with consequent variations in agricultural conditions comparable to those occurring from Rome to Denmark. Consequently research, to benefit the individual farmer of this province, must relate all findings to these varying conditions, and to be economically sound it must avoid duplication and overlapping by adoption of a programme so fundamental that interprovincial and international collaboration and coöperation may be possible. Adoption in this country of cultural methods and crop varieties profitable in others, and successful introduction into foreign countries of our improved varieties of seed, will depend upon intimate comparisons of local and foreign environmental coincidences. Such comparisons can result only from a basic agricultural research programme with possibilities of international application.

Aims of an Agricultural Research Programme

1. To supersede scattered and unrelated agricultural research action by a definite and comprehensive plan holding possibilities for unlimited expansion and adaptation to changing conditions and needs.

2. To provide a basis so fundamental that all future research progress will contribute to the original design and not entail continuous scrapping and rebuilding of research programmes.

3. To provide a structure for agricultural research which will be applicable internationally as well as locally and so provide a basis for international collaboration.

4. To stimulate research effort by facilitating collaboration between individual scientists and groups of scientists. To provide a common ground for interrelation of isolated branches of agricultural research and to prevent repetition and duplication of research effort.

5. To provide a clearing-house for filing and interrelation of research data for the purpose of immediately relating research findings to practical agricultural problems. Owing to the great diversity of agricultural environmental coincidences, general findings are of little value until definitely considered in the light of local environmental factors.

6. To simplify and classify research findings and interpret them in terms of actual farm practice for the benefit of individual farmers.

7. To define the various environmental coincidences under which agriculture must proceed in any given area. These are for the most part fixed and unchanging and so provide the only stable basis for a permanent agricultural policy. The use to which we may put our agricultural possibilities will no doubt change as science advances and as economic changes indicate, but the fundamental conditions under which the industry must operate, the primary factors of soil, climate, light, latitude, topography, geological

formation, and their complicated interrelation with each other, are stable. Once these agro-ecological coincidences are determined we have laid the only sure foundation for application of the research findings of geneticists, economists, entomologists, pathologists, etc.

In an endeavour to bring such organized research effort to bear on the problems of agriculture within this province, the Ontario Research Foundation has outlined a programme and is carrying out a policy of regional research which demonstrates the value and simplicity of such organized investigations on a large scale, and the possibilities it offers as a basis for interprovincial and international collaboration.

Necessity for Division of Agricultural Areas According to Ecological Characteristics

A preliminary survey of the province of Ontario showed that our present political division into counties shows no relation to agricultural characteristics as disclosed by agro-ecological studies, although in the absence of more suitable divisions counties have formed the basic units for agricultural extension services and for soil surveys, etc. An ecological survey shows many nuclei of distinct environmental coincidences indicating the necessity for individual crop selection and cultural procedure. Many other distinct environmental coincidences are present throughout the province but their characteristic features are not as obvious and require more intensive investigation for determination. Even those areas which have outstanding environmental features, definitely marking them as pre-eminently suitable for certain types of agriculture, require much ecological study to establish definite boundaries. Such regions are the Essex-Kent district, the Niagara fruit belt, the dairy section centred around Oxford County, the clay belt in Northern Ontario and a narrow strip along the north shore of Lake Ontario. Research has not yet definitely established the boundaries of these regional coincidences, but agricultural experience and ecological studies have already demonstrated their suitability for characteristic types of agriculture.

The initial step in our provincial programme is the division of the province into these numerous regions indicated by ecological research. Each of these regions constitutes what we have designated as a *major environmental coincidence,* signifying that certain fundamental environmental factors are fairly constant throughout the entire district. The environmental factors which are most characteristic and chiefly influence the agriculture of one major coincidence may not be the same which determine boundaries in another. In one region soil may be the decisive factor, in another climate, in another topography or geological formation.

In most regions it is found that there are several factors common throughout and one or more which determine the boundaries. The boundaries of all environmental coincidences are more or less arbitrary although variations due to geology, soil, or topography, are usually more definitely marked than those attributable solely to climatic conditions. In the Niagara fruit district for instance the moderated climate is due to its peculiar topography and the Niagara River, Lake Ontario and the Niagara

Escarpment form clearly defined boundaries on east, north and south. As the western end of the belt is reached climatic changes are very gradual and the changes in fruit crops in the western end are due to soil as well as climate. Throughout the entire length of this tender fruit area are many variations in soil and topography which make variation in selection of tender fruits necessary. The conditions of light, temperature, rainfall, length of season and other interactive factors are practically constant throughout the district. The Essex-Kent area has approximately the same mean temperature as the Niagara District but the lower minimum temperature in the dormant season and the fact that the growing season, although the same length, starts and ends earlier makes a difference in choice of crops expedient.

Figure 1. Silage corn 12 feet high on Stony Madrid Soil. Yield excellent. Major coincidence favourable. Minor coincidence favourable.

The Eastern counties of Ontario have been found to comprise a major coincidence having uniform duration and intensity of light, temperature, precipitation, altitude, length and occurrence of growing season, and underlying rock formation. The chief variations within the region are in depths and types of soil which individually further limit choice of crops but do not change the general type of agriculture suitable for the district. Each of these distinct variations within the major coincidence we designate as *minor coincidences*. They are subject to all the limitations of the major coincidence with further limitations peculiar to each.

This region of Eastern counties has been chosen to demonstrate the regional research programme based upon the application of the environmental coincidence principle of crop distribution. It is called Ontario Regional Coincidence No. 1, or briefly O.R.C. No. 1. This type of nomenclature is not confusing and can easily be expanded to apply to all provinces by simply using the initial or initials of each province.

Ontario Regional Coincidence No. I.

Extent.—Comprises that Eastern section of Ontario bounded on the north by the Ottawa River, on the east by the Province of Quebec, on the

Figure 2. The chief characteristics of Ontario Regional Coincidence No. 1.

1. Practically all underlaid with sedimentary rock.
2. Practically all level or gently undulating country.
3. Low elevation average about 325 ft.
4. Poor drainage over large areas.
5. Nearly all soil lacking in lime in upper horizons.
6. Large areas of shallow soil.
7. " " " peat and muck soil.
8. " " " stony soil.
9. Growing Season. Wide range of daily temperature 20.8°F. Fairly regular supply of rainfall—Average 11 days a month. Fairly long day at beginning of growing season tapering off to short day at close. Intensity of light medium. Relative humidity high. Maximum intensity of coincidence for growth reached in month of July. Summer temp. extremely high—Max. 104°F. Prevailing wind—westerly. Thunder storms, average 22 .
10. Dormant Season. Winter snowfall heavy—97 inches—but snow blanket unsteady. Winter temperature extreme—33 below.

south by the St. Lawrence River and on the west by an arbitrary line from Arnprior through Perth to Brockville. All boundaries of environmental coincidences are more or less arbitrary although variations due to geology or soil are usually more definitely marked than the more gradual changes attributable to climatic conditions. In this coincidence the sedimentary formation mostly of limestone underlying this region became the limiting characteristic.

Latitude, longitude, area, etc.—are recorded on the accompanying map.

Geology.—As these records are intended primarily for practical application to agricultural problems, only those characteristics having a direct bearing on that industry are considered. Geological formation is important in so far as it affects structure, fertility and chemical constituents of soil, and the type of agriculture practised.

Practically all of this area is underlaid with sedimentary rock, mostly Black River and Trenton Limestone, and approximately twenty-five per cent of the region consists of extremely shallow soil with frequent outcrops of this limestone. The weathering of outcrops and the chemical results of disintegration of underlying rocks have very important effects upon soil fertility and various types of plant growth. Along the northern and western boundaries where the thinner sedimentary deposits have disappeared through weathering, we find occasional outcrops of the underlying precambrian foundation. Throughout the area are many drifts of glacial deposits containing sand, gravel, and boulders of various sizes which considerably influence the types of soil and agricultural methods practised.

Topography.—Gently undulating with large areas of almost level country. Many glacial ridges run east and west. Frequent sand plains and sand dunes occur, varying in height up to 100 feet. Practically all drainage is toward Ottawa River. There are many low, level, areas of peat bog which present serious drainage problems, and much alluvial soil along low level areas skirting river bank. Elevation generally ranges from 200

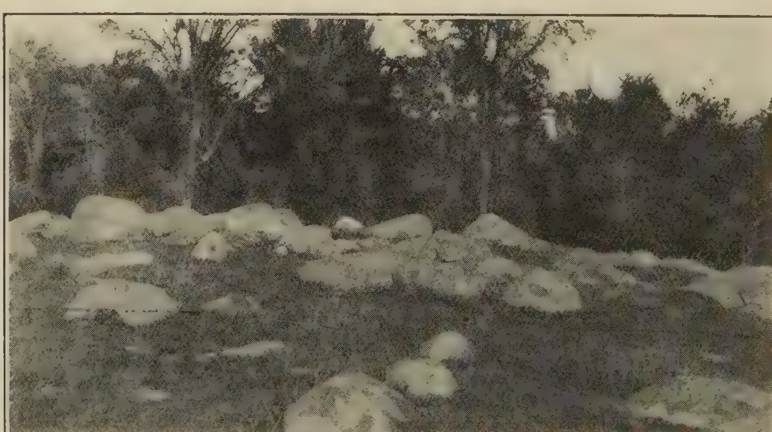

Figure 3. Rocky Madrid. Glacial deposits render much land unfit for anything but pasture.

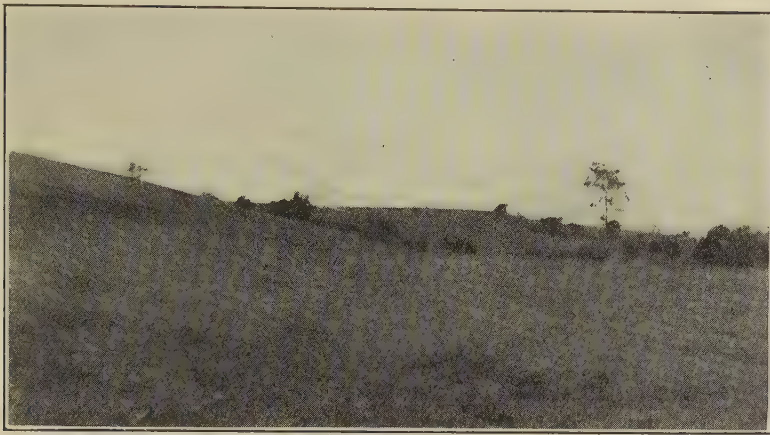

Figure 4. Topography—level or undulating.

feet to 450 feet above sea level. The areas along the Ottawa and St. Lawrence rivers are lower and smoother than central undulating land or areas ridged by glacial action. There are no true hills in this region.

Elevation.—Elevation has a marked influence on temperature, rainfall, and light conditions, and in areas of great variation in elevation there is a corresponding variation in climate and in land utilization problems. Temperature decreases 1° for every 300 feet of elevation. As this region varies less than 300 feet throughout there are no problems of crop distribution arising from this source.

There is also a distinct relationship between type of soil, topography, precipitation, and soil moisture, for even slight slopes have marked influence on the retention of moisture in the soil, and the amount of regional precipitation available to plant roots. For instance, a sandy soil with an impervious subsoil in area of heavy precipitation may suffer seriously from diminished oxygen in the soil if on the level, but the same soil on a slope with favourable distribution of rain will provide optimum moisture and oxygen for certain crops. The influence of various types of subsoil may be greatly modified by variations in topography. Consequently, precipitation, type of soil and topography must always be considered in relation to each other in computing the amount of moisture available for vegetation in any region.

Natural Flora.—The distribution of natural flora is an invaluable indicator of the sudden and frequent changes in soil conditions in such regions as this. With climatic and allied factors fairly constant it is evident that the primary causes for the great diversity in natural flora must be attributed to variation in soil types, topography, drainage, chemical reaction, depth of soil, and the numerous other influences which, apart from climate, control natural distribution.

Individual plants differ in their ability to obtain nutrients and moisture from the soil, in ability to adapt themselves to impervious soil, to long droughts, to poor ventilation and to different heights of water table. This

Figure 5. Natural plant associations on Peat and Muck soils—Larch and Erica predominate.

varying ability is reflected in characteristic root systems suited to different soil conditions and the changes in natural flora reflect equal variations in root environments. The white cedar, for instance, with its spreading system of closely massed fibrous roots is adapted to obtaining moisture and nutrients from shallow soils or those of unusually high water table. Extremely shallow soil may be identified by absence of all flora except grasses or brush.

The gradual blending of hard woods and evergreens in O.R.C. No. 1 marks the southern boundary of the physiologically dry long dormant seasons of the north. The paper birch flourishes on podsol soils but timber on the whole is much larger on the brown forest soils.

Natural plant associations are highly indicative of the optimum survival coincidences for various types of plants, but as most plants have capacity for much greater use of daylight, moisture, etc., than exists in

Figure 6. Sugar maples do well on Madrid Soils.

Figure 7. Typical tree flora of a Rubicon Soil. Birches, Poplars and Maples.

survival coincidence these natural associations are valuable chiefly as indictators of conditions least favourable to attacks of parasites and diseases.

Too great significance should not be placed on natural distribution as indicators of agricultural possibilities and limitations. It is merely an indicator of present conditions which may be greatly altered by liming, drainage, irrigation, addition of fertilizers, introduction of humus and other means of increasing agricultural value of land.

Fauna.—Owing to the superacidity of podsol soils, angle worms are completely absent from them. Consequently these soils are often deficient in aeration. Ants are extremely abundant in sand dunes. A study is being made of occurrence and distribution of insects, birds, mammals and other insects in the district, but records are incomplete.

GROWING SEASON

I. Length and occurrence.—May 7th to September 30th, 146 days.

These dates mark the average occurrence of killing frosts at the beginning and end of growing season. As September 30th is merely the average date for killing frost in the fall, it is evident that dependence upon crops which require this maximum to reach maturity would be unduly hazardous. Killing frosts may occur much earlier or be delayed until later dates. In considering those crops in which length of season is a limiting factor this possibility of frosts for a considerable period at either end of season must be considered and varieties chosen which promise maximum yield at minimum hazard. The occurrence of the growing season is also very important in relation to length of day, distribution of rainfall and other factors. The later the beginning of the growing season, the greater the length of day and the higher the temperature of air during and immediately following germination of seed. For instance, in some coincidences with an early growing season germination and early growth take place during short days and longer nights, with the days gradually increasing until longest day of season, and then gradually decreasing. In other coincidences germination may just commence at or near longest day and

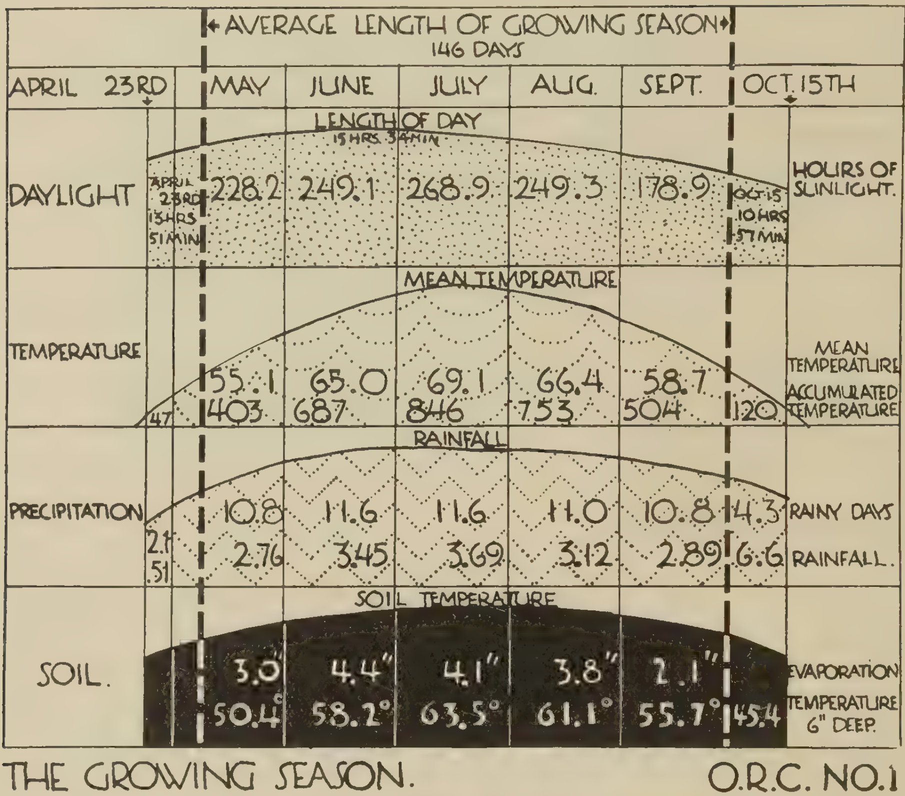

Figure 8.

growth take place under a gradually shortening day until maturity of crop. This distribution of length of day during growing season is very important in its interrelation with moisture, temperature, etc., and their combined effects on rate and type of growth. Such diversities in growing coincidences are governed by dates of opening and closing of growing season.

II. Light.

A. *Duration of light.*—Length of day average—14 hrs., 4 min.
Longest day—June 21st.—15 hrs., 36 min.
Shortest day—Sept. 30th.—11 hrs., 45 min.
Length of day at beginning of growing season—May 7th—14 hrs., 8 min.

As indicated above, variation in length of day during the growing season is very important and must be considered in conjunction with temperature and moisture in calculating possible rate of growth at any period. That individual species and varieties require different duration and intensity of light for vital processes has been indicated by natural plant distribution and confirmed by research. With cultivated crops various types of development may be desired and the optimum light conditions for such development may differ considerably from the light conditions of the survival coincidence.

The length of day necessary for flowering and seeding of lettuce, for instance, is quite different from that necessary to produce marketable heads. Control of light in lettuce culture either through time of planting or reduction of intensity is effective in preventing seeding. Some plants have the ability to make use of much longer periods of daylight than found in their natural habitat or survival coincidence. Potatoes, for instance, increase storage of carbohydrate under long daylight conditions when moisture, soil and temperature are favourable. Corn for fodder finds optimum light at longer day than the optimum for seed corn. The length of day in O.R.C. No. 1 is ideal for yield of silage corn. It is also favourable for storage of carbohydrates in potatoes but the possibility of extreme heat during growing season makes growing of late potatoes as a cash crop hazardous. In some cool seasons yields have been high because temperature is the only limiting factor on the suitable soils.

B. *Intensity of light.* In this region intensity of light is medium due to latitude, altitude, and number of partially cloudy and completely cloudy days.

Hours of possible sunshine during entire growing season, 2337.5.

Average hours of sunshine during entire growing season, 1,117.2.

May	171.2	Aug.	249.3
June	249.1	Sept.	178.9
July	268.9		

Intensity of light and duration of light are so closely associated in their influence on plant growth that it is difficult with our present knowledge to altogether differentiate their effects. We find, for instance, in potato growing that, all other conditions being equal so far as science has discovered, higher altitude in one region will compensate for a more favourable latitude in another. In fruiting, however, adequate duration seems to be essential. Intensity of light, on the other hand, controls the shape and structure of certain vegetation as shown by the difference in formation between forest associations and vegetation grown in the open. The structure of the same species or variety of plant changes considerably under varying light conditions, and in planning crop distribution optimum light requirements for the types of growth required of individual plants must be supplied.

III. Moisture.

Rainfall—average number of inches for district	14.27
average number of inches for Ottawa	15.43

average monthly for Ottawa:

				extremes per month on record:	
May	2.07	Aug.	3.12	Max.	7.43
June	3.45	Sept.	2.89	Min.	.12
July	3.69				

In many regional coincidences having great variation in topography, elevation, and air currents, there are corresponding diversities in amount of rainfall within limited areas. O.R.C. No. 1 is, however, a low comparatively level area with uniform prevailing wind, and there is little variation

either in amount or occurrence of rainfall. Although there are no complete records of monthly averages for the whole district those available show about the same relation to the Ottawa monthly averages as the regional seasonal average does to the Ottawa seasonal average.

Number of rainy days per month .01 inches or more:

May	11.8	Aug.	11.0
June	11.6	Sept.	10.8
July	11.6		

The amount of moisture necessary for maximum yield varies for individual species and varieties of plants and is also modified by the type of growth desired and the part of plant which constitutes crop. It is not only the total available moisture which controls plant growth, for distribution of rainfall is equally as influential as total rainfall in determining the suitability of any coincidence for an individual crop.

Some crops have root systems which are adapted to long periods of drought. They have peculiar ability to reach after and retain moisture and are accompanied by a leaf system which loses minimum moisture through transpiration. Other plants are dependent upon frequent rainfall, the frequency modified by the type of soil, or by irrigation. Experiments with corn have shown that distribution of rainfall according to individual months and stage of growth of corn has marked influence on yield. Low rainfall in May and July and high rainfall in June and August resulted in increased yields of corn. Other crops require different monthly distribution for maximum yields.

Plants receive moisture from three sources, aqueous vapor, precipitation and ground water. In planning land utilization it must be recognized that the known moisture requirements of a given plant may be supplied from all these sources. The amount availalble to vegetation from all sources is controlled by permeability of soil, evaporation, capacity of soil to hold water and the power of the soil to raise water to a height where it is available to individual root systems.

The type of soil, nature of subsoil, evaporation and height of water table must therefore all be considered in relation to total rainfall in calculating the distribution of rainfall favorable for individual crops in definite regions. It is obvious that the optimum distribution and amount in combination with one temperature, soil and topography, might be quite inadequate, or excessive in another coincidence.

On shallow soil such as that present in much of this region, vegetation is much more dependent upon climatic conditions for necessary moisture than is the case on deeper soils. Consequently, frequency of rainfall and power of soil to retain moisture are major factors in determining crop distribution in this area.

In addition to the shallow soils, sandy soils with loose gravelly subsoil such as the madrids (common in this coincidence) are dependent upon regular and frequent rainfall for moisture. This is due to their inability to retain moisture and the inability of a subsoil of loose faulty structure to raise ground water by capillary action.

While the abundant and frequent rainfall is favorable for many of the soils in this coincidence there are some conditions under which it presents problems in drainage. All low-lying heavy soils, peat bogs, black mucks, etc., suffer from excess moisture and provide optimum conditions for development of bacterial diseases on crops unless artificially drained. All plant roots require air for respiration, consequently they will not thrive in a coincidence having abundant precipitation in conjunction with an impervious subsoil or poor drainage as this excess moisture materially decreases oxygen in the soil. The oxygen content necessary for growth varies with individual plants as evidenced by natural distribution.

IV. Temperature.—

Mean 63°F.		Mean maximum	74.2°F.
		" minimum	54.61°F.
Mean monthly in °F		Accumulated monthly	
May	55.3	274.9	
June	64.9	687.0	
July	69.3	846.3	
Aug.	66.3	753.3	
Sept.	58.8	504.0	

Extreme highest 104°F. Mean daily range 20.8°F.

Total accumulated temp. for season—3,057.5°F.

Soil temperature	6 inches	Vary with different soils.
	12 "	Records incomplete.

All phases of heat distribution throughout the year, during growing season, dormant season, individual months, and even daily mean, have significant influence upon plant growth. Just as distribution of moisture at various stages of growth affects individual plants according to their peculiar requirements in this respect, so occurrence and duration of heat at every period of growth is equally important and is complicated by the amount of moisture, light, etc., available to the plant at the same time. The temperature during germination exerts great influence over all future development of plant and optimum temperatures vary with individual plants.

In some sections of Ontario the growing season starts while days are still short and days and nights comparatively cool. In other sections the beginning of the growing season is accompanied by long and proportionately warmer days. Some coincidences have short seasons of great activity which mature crops rapidly. Others have the constant comparatively cool temperature so favorable for potatoes, for instance. Corn, on the contrary, requires warm soil for germination and growth, and for seed corn long season is necessary.

O.R.C. No. I is subject to extremely high temperature in summer which makes potato growing hazardous but is ideal for corn. The low winter minimum prohibits tender fruits. When occurring in conjunction, extreme heat, long days, and excessive moisture, are conducive to disease on many crops and must be considered in relation to each other in every region. High temperature is also conducive to drought by increasing

evaporation; so rainfall, type and depth of soil, topography, and drainage all modify soil temperature. Too warm soil causes malformation of potatoes similar to that of spindle tuber disease.

V. Wind.—West prevailing every month of growing season.

Velocity 7.4

Owing to little variety in topography there are practically no marked local air currents.

VI.—Average relative humidity 83.1

VII.—Number of thunderstorms 22

VIII.—Number of foggy days 1

IX.—Soil evaporation records incomplete.

DORMANT SEASON

Length—222 days

I. Light.—

Length of day—average 10 hrs.
shortest 8 hrs.
longest 13 hrs.

Hrs. of sunshine—907.9, being 36.6 per cent of possible sunshine during this season.

Completely cloudy days—72.

II. Temperature.—

Mean daily—26.8°F.

	Mean by month	Mean daily max.	Mean daily min.
October	46.4°F.	55.2°F.	37.6°F.
November	32.6	39.1	26.2
December	17.3	24.6	10.1
January	11.8	20.8	2.8
February	12.8	22.3	3.3
March	25.1	33.8	16.4
April	42.1	51.9	32.4
May	46.0 (7 days)		

Extreme lowest—33°F. Daily range for season 16.9°F.

Average lowest—22.1°F. Depth of frost 20 to 30 inches.

Disappearance of frost from subsoil from 15th to 30th April depending on type of soil and topography.

Figure 9. The four most common types of soil in Regional Coincidence No. 1.

A. FARMINGTON.

Shallow soil 1 to 3 ft. in depth. Fragments of underlying rock scattered over and through the surface. Usually alkaline. Very early soil. Suitable for early quick-growing truck crops or early pasture.

B. RUBICON (Podsol).

Good drainage. Water table usually high. Poor ventilation. Lack in lime. Very acid. Owing to acidity and lack of air in soil most crops do not do very well.

C. PEAT.

A wet, cold soil and usually very late. Subject to early and late frosts. Difficult to drain. Poorly aired. If properly drained and fertilized will grow fair crop.

D. VERGENNESS CLAY LOAM.

Very smooth or slightly undulating. Soils free of stones and boulders throughout most of the area. Subsoil alkaline. A good soil if properly worked and drained.

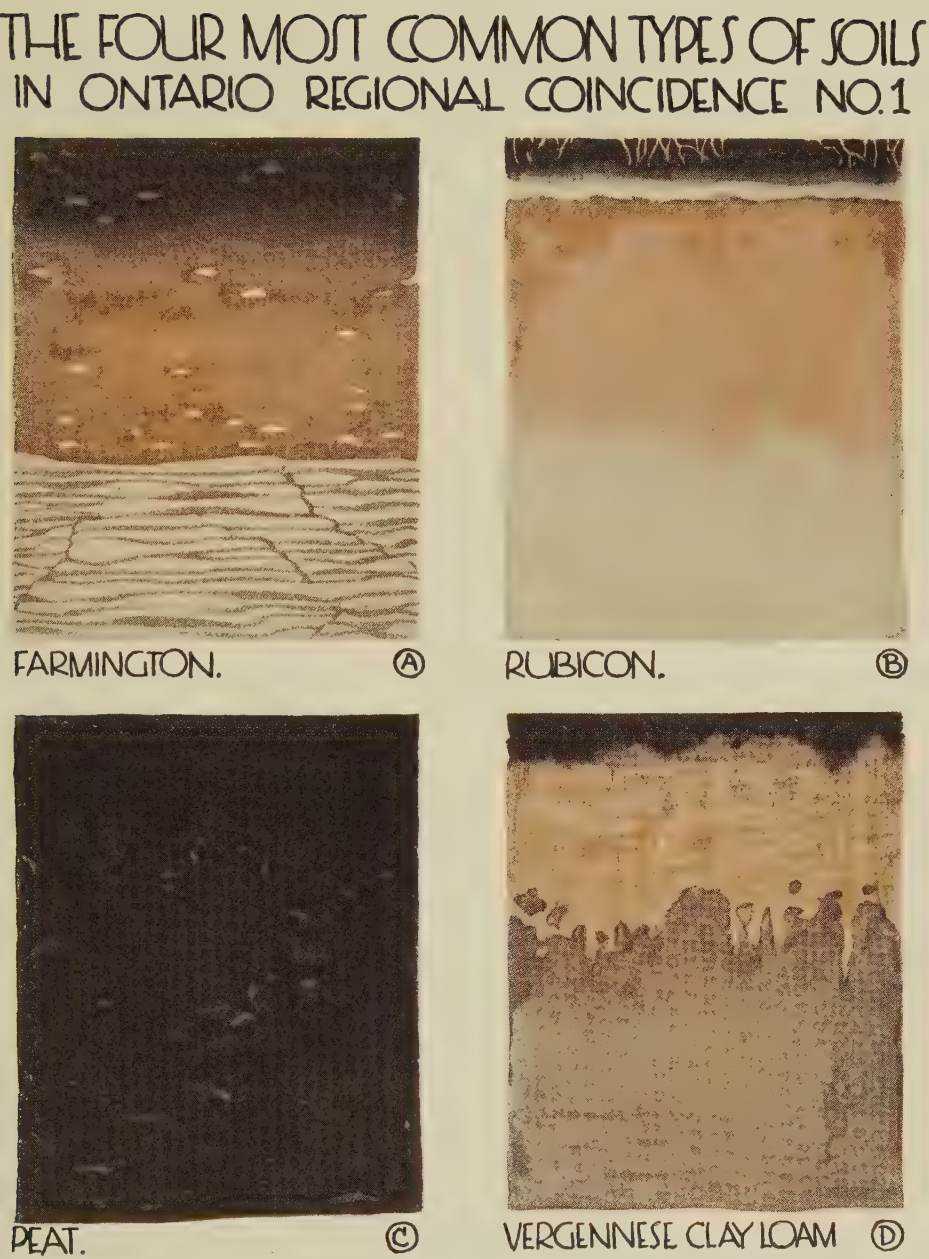

Figure 9. See footnote on page 106.
Colour plate furnished by courtesy of the Ontario Research Foundation.

The occurrence and duration of minimum temperatures during dormant season are most significant and in some coincidences are limiting factor in crop selection. For instance, the total accumulated temperature, and length of season in Essex-Kent coincidence shows little variation from that of the Niagara fruit belt but the low minimum temperature during dormant season in Essex is very detrimental to peach production. In O.R.C. No. I the low minimum temperature may have little influence in limiting crop selection but must be considered in its relation to other factors affecting dairy industry, poultry raising and other activities common to the district.

III. Moisture.—

Average snowfall for 35 years—97.1 inches.

Total precipitation—18.51 inches.

Number of thunderstorms—2.

Number of foggy days—3.

Snow blanket not definitely determined.

Investigations have been carried on at Ottawa for two years to determine depth and constancy of snow blanket which is more important in effect upon agriculture in this district than total snowfall. In more moderate regions with higher winter temperatures and little frost in soil the total snowfall is more effective in adding to soil moisture and is not as valuable as a protection for winter annuals, biennials, and perennial crops.

IV. Wind.—Prevailing west. Velocity—7.6.

Soils

The variations in types and depths of soil are the most significant causes of diversities in agricultural possibilities in this region. As pointed out above this major coincidence is singularly uniform in underlying rock formation, topography, elevation, rainfall, temperature, light and wind. The chief variable is the soil and each individual type in combination with the nonvariable factors forms a "minor" environmental coincidence having distinctive agro-ecological characteristics and requiring individual consideration to determine most profitable utilization.

There are in all sixteen distinct soil types in this region, each offering distinct potentialities, limitations, and agricultural problems. Some idea of the great diversities in soil conditions within limited areas may be gained by the following brief notes on the variations in O.R.C. No. I.

Podsol-Rubicon.—Comprises about 25 per cent of soil in the region, and most virgin forest soils of northern Ontario. Characteristics—extremely acid; depth—varies from around four feet to extreme depth. The very shallow soil in this district is never podsol as the disintegration of underlying limestone counteracts acidity. Podsol soil is not easily distinguished after it has been worked for some time but on roadside cuts beside cultivated fields or forests it is easily identified by a characteristic layer of ashy coloured sand, 2 to 5 inches deep below humus layer, and

Figure 10. Sand drift areas present a serious menace to agriculture in the western end of region.

by brownish streaks through lighter subsoil showing the iron which has leached from ashy layer. This soil has high degree of lime deficiency and the choice of crops which thrive without addition of lime on this soil is very limited. It is too acid for corn, and clovers for instance, which find favorable conditions when the same climatic and light conditions are found in conjunction with some other soils in this region.

Peat.—Three distinct types, comprise large areas in this region,—more than in all other parts of the province. Depth in central portion about 10 feet. Those near Ottawa which have been successfully drained and fertilized with phosphorus and potash produce good crops of barley, celery and other garden crops. Drainage presents the chief problem.

Sand dune areas.—Constantly changing in height and shifting in position. Sometimes several layers of vegetation have been buried under fresh deposits of sand. Most sand dunes in the district are characterized

Figure 11. Calcareous root-like structures on sand dune near Kemptville.

by calcareous deposits of stump-like structures from 1 to 3 feet in height, and mushroom-like structures almost forming carpet in some sand formations. Unsuitable for agriculture.

Farmington.—Shallow sandy loam varying from few inches to 3 feet in depth. Disintegration of limestone underlying this soil is rapid and fragments are scattered through soil. Lower layers are strongly alkaline, upper layers usually alkaline but do not always effervesce. Frequent outcrops of limestone and glacial deposits of boulders occur on this soil. The moisture content of this soil is dependent upon climatic conditions and for that reason well distributed rains are essential for successful agriculture. Because of their lack of moisture-retaining capacity, and possibility of extreme heat in this region, the shallower soils offer too great hazard in cropping. The depth of soil and topography regulate the agricultural value of this land.

Madrids.—Four types. Madrid loam—scattered stones.

Stony madrid—stones 3 to 8 inches, abundant.

Sandy madrid—1 to 3 ft. of clear sand on surface, gravel below.

Rocky madrid—large rocks and boulders.

Mostly give neutral to alkaline reaction. Comparatively fertile. Grow splendid crops of corn, clover and potatoes. Some subsoils looser and more gravelly than others, except madrid loam, do not retain moisture from rainfall or increase it by capillary action. The nature of subsoil and topography must be considered in cropping. Rocky madrid is most frequently utilized for pasture as the large rocks and boulders prevent cultivation. The number and size of stones on these soils considerably influence type of mechanization.

Lyons Stony Loam.—Low, poorly-drained stony land. More or less acid. Excessive moisture causes oxygen deficiency and provides favorable conditions for development of diseases on crops. Cultivation is difficult

Figure 12. Sandy Madrid soil—2-3 feet sand on surface with sand and gravel below. Suitable for crops requiring good aeration and drainage.

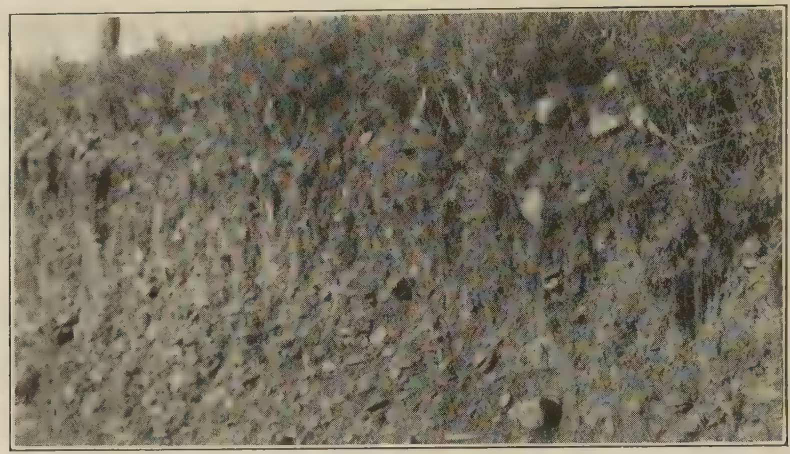

Figure 13. Stony Madrid. A warm early soil suitable for most crops.

because of stones and draining is difficult because of situation in low-lying depressions. Most suitable for pasture or timber land.

Vergennes.—Vergennes loam
" silt loam
" clay loam

Neutral to slightly acid on surface. Lower layers alkaline.

Vergennes Loam.—Loose, light top soil, heavy sticky subsoil sometimes coming near surface. Good aeration in top soil and grows splendid crops in this district when either natural or artificial drainage is adequate.

Vergennes Silt Loam.—Also has compact subsoil which presents drainage problems particularly in level or nearly level areas.

Vergennes Clay Loam.—Heavy, sticky soil but yields good crops when properly worked and well drained. Owing to occurrence of this soil in lowest elevations of district, natural drainage is usually insufficient and artificial drainage presents problems. Where drainage is inadequate for tilling, land is used for pasture.

Granby.—Very heavy in humus; occurs in low lying areas and is very difficult to drain; high water table, mostly in timber or pasture. In some sections hay is cut but usually yield is poor and quantity inferior. Drainage would greatly increase value of land.

Rock Outcrops.—Large areas of exposed rock interspersed with soil pockets of varying sizes. Some large enough for pasture, others just large and deep enough to support brush or scrub timber.

Marl Deposits.—Large areas which could be economically used to supply deficiency of lime in acid soils of region.

A complete study of soils in Ontario may show that some of the above types are peculiarly characteristic to this district and the similar formations in the adjoining counties of New York State. Other types may recur

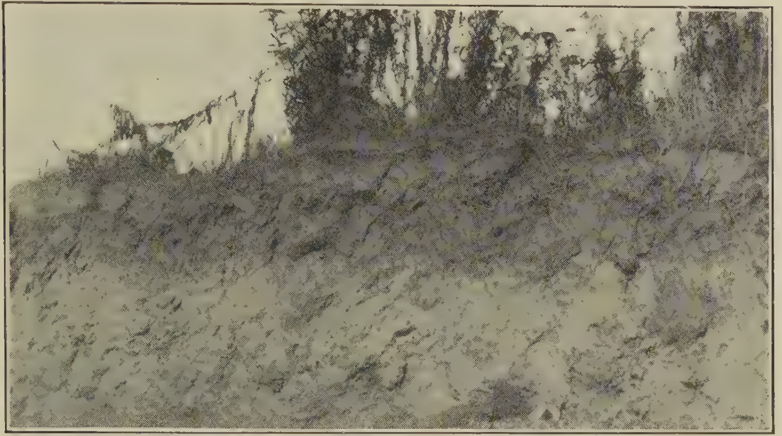

Figure 14. Granby Fine Sandy Loam. A common type of soil in the lower areas. The surface soil consists of dark brown or dark greyish-brown loam 8 to 10 inches thick. This is underlain by greyish fine sandy loam in most cases mottled or streaked with yellow and brown.

in various environmental coincidences in other parts of Ontario. But when we consider the variation in latitude and length of day existing in Ontario, that rainfall varies from 20 to 40 inches according to location, that there is equal diversity in mean temperatures in length of growing season, in elevation, in topography, and in all the other factors which control plant development on any soil, the futility of considering soil types apart from other factors is obvious. *A soil type holds no definite potentialities apart from the coincidence in which it occurs, and land utilization advice is sound only when soil types are viewed in relation to other interactive factors.*

Recognizing this fact and also the fact that maps calculated to show the accurate occurrence of soil types in a district of this kind are impractical, it was realized that some means must be established to assist the farmer and extension service in recognizing the soil types with which they

Figure 15. Shallow soils with limestone rock outcrops are very common in the western end of the region.

are working. Then with accurate data available covering the possibilities, limitations and best methods of tilling each type under a definite environmental coincidence, it would be a simple matter for the farmer and extension service to adapt this information to the farmer's own problem, where slight variation in topography, exposure, or ease of drainage mighty modify general conclusions.

For this reason profiles are prepared and exhibited under glass showing exact structure of each soil type. As many soils change colour on exposure to air these profiles are further supplemented with paintings made in the field at time of exposure of profile, showing true coloration.

It has become evident that soil maps could never be made sufficiently accurate to benefit the individual farmer, and that chemical analysis of soil types must also be made locally because chemical analyses are not uniform throughout individual types of soil. Consequently, all that is necessary for a programme such as we are outlining is to determine the various types within a coincidence and study them in relation to local conditions. It is possible to identify all the soil types in an entire region of this size in a fraction of the time necessary for a detailed soil survey of one county.

INSECT PESTS AND DISEASES

Occurrences of insect pests and diseases are associated with individual crops and varieties and are aggravated or minimized by local conditions. The diseases and pests which attack crops in this region are very different from those causing losses in the fruit belt, in wheat sections, in tobacco coincidences, or even in some other dairy coincidences. The diseases attacking oats, for instance, are different from those on the same crop prevalent in the Sudbury coincidence where different light and climatic conditions prevail. It is obvious that disease control must be viewed in the light of local growing conditions, crop distribution, selection of varieties most immune to attack under given coincidence, and the possibilities for remedying unhealthy soil conditions. There is also a definite relation between local climatic and soil conditions and the occurrence and control of insect pests and animal parasites. Consequently, all general and abstract research findings must be viewed in the light of local conditions, and control measures modified to suit local needs and problems.

Discussion

It is impossible in the space at our disposal in this paper to cover in detail the various lines of investigation followed. This is merely an attempt (1) to outline the structure of a regional research programme, based on recognition of the necessity of considering all modifying factors in relation to individual environmental coincidences, and (2) to show that any Ontario programme, while aiming primarily to benefit the industry within the province, must at the same time if economically and scientifically sound provide a basis for inter-provincial and international collaboration and coöperation. No agricultural policy for research, education, marketing or even emergency measures of relief can be sound which fails to view the industry as a unit, and a unit in which low cost of production of plant crop is the common basis and the primary goal towards which all efforts

must be focused. Every branch, whether dairying, cattle-, hog-, sheep- or poultry-raising, as well as those in which cash crops are in the form of plant yield, has its foundation in this fundamental phase of the industry and other problems are secondary. We have not attempted to outline the economic end of the investigation to determine the diversities in the costs of production of individual crops and farm products throughout this region. Investigation showed, however, that actual yields and costs under present methods and crop distribution corroborated the previous conclusions of research based on comparisons of actual environmental coincidences in the region with the optimum requirements of the various plants grown. In so far as these have been determined our preliminary investigations have already resulted in conclusions of value to agriculture in this district. For instance, we find that climate, soil and cultural conditions generally indicate dairying as the most profitable form of farming. Although experience has resulted in the same conclusion the distribution of those crops essential to the dairy industry is still in the trial-and-error stage. Misuse of land is common and a source of great loss by raising cost of production of individual crops. Many failures in the essential corn crops, for instance, are due to the failure of farmers to distinguish types of land and to plant corn on the soils which provide the necessary conditions for profitable yields.

LAND SETTLEMENT

The far-reaching significance of such fundamental research as a basis for land settlement is at once apparent, for accurate knowledge of agricultural possibilities is essential to any sound land settlement scheme. Great saving of public money and prevention of individual privation may be effected by determining the potentialities of land before settlement is effected. By this means submarginal land may be labelled as such and much costly abandonment and rehabilitation avoided. Good agricultural land, on the other hand, may be utilized in the most profitable manner, viewed from both individual and national standpoints and as a long-range proposition rather than a seasonal gamble. The fact that our average yields per acre show little or no increase during the last forty years, in spite of the stupendous strides in genetics, use of fertilizers, improvement in cultural methods, and other advanced practices indicates much misuse of land and losses due to necessity for individual experiments to discover agricultural possibilities of land.

MARKETING

At the present time the problem of marketing agricultural produce is receiving much consideration, but the greatest obstacle to any satisfactory solution lies in the great diversity of yields and consequently in costs of production of individual crops throughout the province. As long as such diversities exist success in any form of coöperative selling is possible. Stabilization of production costs through elimination of these diversities in yields per acre will automatically follow a policy of crop distribution founded on accurate knowledge of environmental coincidences as compared with optimum requirements of individual crops and varieties. With marketing problems international in scope our only hope of successful

competition lies in scientific land utilization with stabilization of yields per acre and production costs.

FERTILIZERS

The use of fertilizers is another problem which is very much to the fore in recent years. Research has revealed that general recommendations as to applications of fertilizers whether in relation to individual crops or particular types of soil are insufficient. Applications which increase yields and prove highly profitable under one environmental coincidence may be quite inadequate or uneconomic in another. All investigations and experiments in reaction of crops to quantities, types or mode of application of fertilizer should take cognizance of this great diversity of agro-ecological conditions under which such applications must eventually be made. Sound recommendations for such procedure must be based on recognition of the needs of each crop under the individual coincidences under which it may be profitably grown in any area.

Acknowledgements

The writer wishes to thank Dr. H. B. Speakman, Director of the Ontario Research Foundation for many helpful suggestions during the course of this work and also wishes to acknowledge indebtedness to Prof. W. J. Bell, Director of Kemptville Experimental Farm and Agricultural School; Dr. C. S. Hanes, Ontario Research Foundation; Mr. E. S. Hopkins, Agronomist, Dominion Experimental Farm, Ottawa; Mr. F. F. Morwick, Chemistry Department, Ontario Agricultural College, Guelph; Mr. A. J. Connor, Meteorological Department, Toronto; Mr. H. G. Nixon, Superintendent, Demonstration Farm, New Liskeard; Mr. R. G. Newton, Dominion Experimental Farm, Invermere, B.C.; Mr. C. H. Metzger, State Horticulturist, Colorado Agricultural College, Fort Collins, Colorado, U.S.A.; Dominion Development Board, Ottawa; and Dr. R. R. McKibbin, Chemistry Department, Macdonald College, Ste. Anne de Bellevue, Que., for much valuable information and scientific data.

LA FERTILISATION DES PATURAGES [1]

L'argent investi dans la fertilisation d'un pâturage a donné en trois mois des bénéfices importants cette année sur la ferme de M. Victor Aylward à Upper Falmouth, Nouvelle-Ecosse.

Le but de l'expérience était de comparer un acre de pâturage recevant 800 livres d'un engrais 4-8-7 avec un acre du même pâturage non fertilisé. On choisit pour cela un vieux pâturage en mauvaise condition. Les 800 livres de 4-8-7 furent appliquées le 17 avril. La parcelle fertilisée comme la parcelle témoin furent encloses afin qu'on puisse obtenir des chiffres exacts concernant le nombre de jours de pâturage et la production laitière.

Depuis le commencement de la saison jusqu'au 15 juillet 1931 les résultats suivants furent obtenus:—

	Nombre de vaches	dates de la pâture		Nombre de jours	Nombre total de jours par tête de bétail
Acre fertilisé	19	Mai	24-27	4	76
	20	Juin	16-19	4	80
	23	Juillet	11-14	4	92
Acre non fertilisé	19	Mai	28-29	1½	29
	20	Juin	20-21	1½	30

Comme au 14 juillet il n'y avait pas assez d'herbe sur la parcelle témoin pour qu'on puisse y mettre le bétail à pâturer, l'acre fertilisé donne un total de 248 jours de pâture par tête de bétail contre 59 sur l'acre non fertilisé.

Durant la semaine précédant le pâturage voici quels furent les aliments donnés en nourriture chaque jour aux vaches à l'étable:—

25	livres de	farine de coton	à	$2.60 par 100 livres	.65
100	" "	"shorts"	à	$1.60 " " "	1.60
70	" "	"cow chow"	à	$2.50 " " "	1.75
20	" "	son	à	$1.30 " " "	.26
228	" "	fom	à	$14.00 la tonne	1.61
					$5.87

Comme la parcelle fertilisée fut la première prête on y mit les vaches dès qu'elles quittèrent l'étable, puis on les mit sur la parcelle témoin, puis sur le pâturage principal.

Tant qu'ellles furent sur la prarie fertilisée les vaches refusèrent les aliments de complément, ce qui pour quatre jours représente une économie de $23.48, soit deux fois la valeur de l'engrais chimique.

Non content d'obtenir ces chiffres M. Aylward a aussi tenu un compte exact de la production laitière.

Avant le 24 mai la production laitière moyenne des 19 vaches à l'étable était de 150 pintes.

[1] Rapporté par M. Victor Aylward à M. J. E. McIntyre, Surveillant de la démonstration pour le Conseil des Engrais Chimiques de la Nouvelle-Ecosse.

Le	24	mai	les	vaches	sur	l'acre	fertilisé	donnèrent	169	pintes
“	25	“	“	“	“	“	“	“	196	“
“	26	“	“	“	“	“	“	“	184	“
“	27	“	“	“	“	“	“	“	179	“

L'augmentation pour les 4 jours fut donc de 128 pintes.

Avant le 17 juin la production laitière moyenne sur le pâturage principal était de 162 pintes par jour.

Le	17	juin	les	20	vaches	sur	la	parcelle	fertilisée	donnèrent	175	pintes
“	18	“	“	“	“	“	“	“	“	“	185	“
“	19	“	“	“	“	“	“	“	“	“	180	“
“	20	“	“	“	“	“	“	“	“	“	175	“

L'augmentation durant ces 4 jours fut donc de 67 pintes.

Avant la troisième période de pâturage la production laitière moyenne était 164 pintes par jour.

Le	11	juillet	23	vaches	sur	la	parcelle	fertilisée	donnèrent	180	pintes
“	12	“	“	“	“	“	“	“	“	198	“
“	13	“	“	“	“	“	“	“	“	206	“
“	14	“	“	“	“	“	“	“	“	180	“

Ceci fait une augmentation totale de 108 pintes pour les 4 jours.

Depuis le commencement de la saison jusqu'au 15 juillet l'augmentation de la production laitière sur la parcelle fertilisée fut ainsi de 303 pintes. Dans le cas de M. Aylward le lait a une valeur de 10 cents par pinte. La valeur totale du lait en supplément sur la parcelle fertilisée fut ainsi de $30.30. La dépense pour l'engrais chimique appliqué sur le champ fut d'environ $14.00. Par conséquent un dollar d'engrais chimique a produit une quantité supplémentaire de lait valant $2.16. En outre le pâturage fertilisé fut prêt avant le pâturage non fertilisé, ce qui produisit une économie de fourrage et d'aliments concentrés équivalant à plusieurs jours de nourriture.

M. Aylward estime qu'il lui coûte environ 31 cents par jour pour nourrir une vache à l'étable contre 6 cents sur la prairie fertilisée.

D'après l'aspect général de la prairie au 15 juillet la parcelle fertilisée était en état de donner encore de nombreux jours de pâturage avant la fin de la saison.

8. Proceedings of the Canadian Political Science Association, Vol. III, 1931.

Members of the C.S.T.A. who are interested in administration and extension will find several papers of value in this volume. All these papers bring to our attention discussions of problems of national importance.

It may not be amiss to state that this association was organized in 1913 being the outcome of widely expressed opinions to the effect that the time had come for systematic and concerted investigation of Political, Economic and Social problems that were distinctly Canadian. The Association was unable to function during the war and it was not until 1929 that attempts were made to revive the organization. In May 1930, the second "annual" meeting was held and the proceedings published as Vol. II. The third meeting was held in Ottawa, May 27-29, 1931. While the Association is named "The Canadian Political Science Association, the majority of the papers deal with economic problems. The membership fee is $2.00 and anyone interested in such problems may be admitted.

The officers of the association for 1931-32 are, President, S. J. McLean, Board of Railway Commissioners, Ottawa; Vice-Presidents, Prof. A. B. Clark, Prof. S. B. Leacock, Prof. E. Montpetit and Prof. E. J. Urwick; Secretary, S. A. Cudmore, Dominion Bureau of Statistics; Treasurer, Prof. F. A. Knox, Department of Economics, Queen's University, Kingston.

Papers read at the May meeting were as follows: Canada's Foreign Trade in Agricultural Products, T. W. Grindley; The Economic Aspects of the Agricultural Problems, J. E. Lattimer; The Sociological Aspects of the Agricultural Problem, R. W. Murchie; A. Programme of Research in Agricultural Economics, J. F. Booth; The Mobility of Labour in Relation to Unemployment, Leonard C. Marsh; Some Aspects of Unemployment Insurance, Bryce M. Stewart; How Has Business Forecasting Stood the Test? Lionel D. Edie; Is our Economic System Bankrupt? O. D. Skelton; Gold and The Decline in Prices, W. A. MacKintosh; Transportation as a Factor in Canadian Economic History, H. A. Innis; Is a Revision of Taxation Powers Necessary? H. R. Kemp; The Compact Theory of Confederation, N. McL. Rogers; The Development of Canadian Federalism, F. R. Scott; Some Comments on Dominion Provincial Relations, J. S. Ewart.

J.C.

9. The Outlook for the Dairy Industry and Some Essentials of a National Dairy Programme.

This sixty page bulletin appears as Miscellaneous Publication No. 124 of the United States Department of Agriculture, Washington, D.C., and may be secured from the Superintendent of Documents at the price of 15 cents.

Those who are not familiar with the 'Outlook' type of publication prepared by various Departments of the U.S.D.A., may take this bulletin as a sample of the type suggested for Canada by the Canadian Society of Agricultural Economics. This particular bulletin, edited by Nils A. Olsen, Chief of the Bureau of Agricultural Economics, is an outgrowth of the recent National Dairy Conference held at St. Louis, Mo., on March 11th and 12th, 1931. Here the dairy industry, represented by producers, processors and distributors, considered the problems of the industry and outlined a programme of action. *The Outlook* gives a general survey of the development of the dairy industry in the United States and pays particular attention to recent trends which will lead to a readjustment of the whole industry in that country. This, of course, will have an effect on the Canadian dairy industry, and the bulletin should be studied by all those who are interested in the future of Canadian dairying.

10. Dehydration of Canadian Fruits.

This bulletin by F. E. Atkinson of the Dominion Experimental Station, Summerland, B.C., appears as Dominion of Canada Department of Agriculture Bulletin No. 151, New Series, available from the Publications Branch, Ottawa. Some idea of the immensity of the Canadian market for dehydrated fruits may be gained from the fact that for the three fiscal years ending March, 1929, the average annual importation of dried fruit amounted to 88,798,477 pounds, valued at approximately $7,394,895. The Dehydration Committee of the

Dominion Department of Agriculture has carried on experiments in connection with the dehydration of several fruits grown in Canada. The results of these experiments, together with outlines of commercial processes, are given in this bulletin. Investigations have been carried on in a commercial plant at Grimsby, Ont., at a plant at Penticton, B.C., now under the supervision of the Dominion Experimental Station at Summerland, and with small experimental dehydrators at the Experimental Farms at Saanichton, B.C., Ottawa, Ont., and Kentville, N.S.

11. Important Western Browse Plants.

This publication is a 200 page manual on forage plants grown on the ranges of the Western States. It appears as Miscellaneous Publication No. 101 of the U. S. D. A. and may be secured from the Superintendent of Documents, Washington, D.C., for 45 cents.

The bulletin is very well illustrated and gives an account of approximately twenty-two years' work in the collecting of about 1,000 species of browse plants by forest officers. The species are classified botanically and their value as forage is indicated briefly.

12. Rancid Flavour in Cheddar Cheese.

Bulletin No. 146, New Series, of the Dominion Department of Agriculture, is a study of rancid flavour in cheddar cheese by Dr. E. G. Hood, Chief of the Division of Dairy Research, and A. H. White, Dairy Specialist, of the Dominion Dairy & Cold Storage Branch. It presents a summary of several studies on the occurrence of rancid flavours and makes the following recommendations:

'As pointed out in the present investigation, the main cause of rancidity has been attributed to undesirable bacteria. Such being the case, the tendency for cheese to develop rancid flavour may be effectively minimized by paying stricter attention to the quality of the milk supply, by rejecting low grade milk, and by a general improvement in the supply based on the use of the Curd test and the Methylene Blue test. Troubled factories should pay greater attention to detail in cleanliness and sterilization in all factory operations. Greater care should be exercised in the preparation and handling of starters, in the pasteurization of whey, in the selection of water used for diluting the rennet, and in general factory sanitation. In the final analysis, the control of rancidity lies in the hands of the cheesemaker, in his ability to keep his supply of milk up to a high standard, and in manufacturing such milk under the most ideal conditions of sanitation.'

13. Rural Community Fire Departments.

Farmers' Bulletin No. 1667 of the U.S.D.A. is available from the Superintendent of Documents, Washington, D.C., for 10 cents.

This bulletin presents the summarized results of a field survey of rural fire departments that serve farmers, especially those that concern farmers through ownership or financial interest. Local investigations were made to ascertain the effectiveness of these departments in the reduction of the great fire losses in farming communities and the accompanying social distress. Eighty rural fire departments were covered. Case studies were made of 52 and information was secured locally concerning 18 others. Indirect but apparently reliable information was received concerning the successful operation of more than a hundred others. One from each of the several types of fire organizations giving service to farms is described in this bulletin in the hope that any interested community will find at least one type that would suit its conditions. Although in many places rural fire departments are practically unknown, in other sections they are successfully operating in large numbers. This would seem to indicate that where the successful operation of one such department became known others were soon organized in neighbouring communities.

14. Parasites of Horses.

Dr. A. E. Cameron, Chief Veterinary Inspector of the Health of Animals Branch, Department of Agriculture, Ottawa, has written Bulletin No. 152, New Series, giving an account of internal and external parasites of horses. This bulletin is well illustrated and gives symptoms and control measures for the principal parasites encountered on the farm. Copies are available from the Publications Branch, Ottawa.

CONCERNING THE C.S.T.A.

Notes and News

C. R. MacDonald Holmes (Alberta '27) is now attached to the staff of the Edmonton Bulletin at Edmonton, Alta.

R. G. Emslie (Toronto '28) has changed his address to 82 Mile End Avenue, Aberdeen, Scotland.

W. B. H. Marshall (McGill '28) has been appointed Senior Inspector, Fruit Branch, Dominion Department of Agriculture, Quebec.

J. M. Armstrong (Manitoba '25) will be at the Department of Genetics, McGill University, for the winter. Mr. Armstrong is working under a National Research Council scholarship which he received last spring.

W. C. Hopper (Toronto '20), formerly Chief Assistant, Division of Field Husbandry, Central Experimental Farm, Ottawa, has resigned his position to take an instructorship in agricultural economics under Dr. G. F. Warren at Cornell University, in order to complete the requirements for his Ph. D. degree which he expects to obtain next year.

R. C. Palmer (British Columbia '21) has left for England and will be away for a year. His address is—c/o R. G. Hatton, Research Station, East Malling, Kent.

F. S. Nowosad (Manitoba '31) has changed his address to—Agronomy Department, Macdonald College, P.Q.

C. K. Johns (Alberta '25) has changed his address to — 1004 Vilas Avenue, Madison, Wis., U.S.A.

G. H. Bowen (McGill '23) has been appointed Instructor in the Division of Landscape Architecture at Pennsylvania State College. His new address is—University Club, State College, Pa., U.S.A.

L. G. Heimpel, (Toronto '18) Assistant Professor of Agricultural Engineering, Macdonald College, received the degree of Master of Science from Cornell University last June. Professor Heimpel majored in Agricultural Engineering and his thesis represents the results of three years of study and tests of systems of stable ventilation as in operation in some of the dairy barns near Montreal. A copy of the thesis has been placed in the Department of Agriculture Library, Ottawa .

A. Cairns (Alberta '23) has changed his address to Empire Marketing Board, 2 Queen Anne's Gate Buildings, London, S.W.1.

F. X. Boudrault (Montreal '31) has changed his address to St. Tite, Champlain Co., P.Q.

The following members of the Dominion Entomological Branch attended the annual meeting of the International Great Plains Crop Pest Committee at Bozeman, Montana, in August; Norman Criddle, Treesbank, Man.; K. M. King, Saskatoon, Sask.; H. L. Seamans, Lethbridge, Alta.; E. R. Buckle, Vernon, B.C.

Dr. R. D. Bird has been appointed to the position of Entomologist at the Dominion Entomological Laboratory, Vernon, B.C.

The President of the C.S.T.A., Mr. H. S. Arkell, is leaving for the West early in October where he expects to visit the executives of some of the locals to discuss plans for the season's activities. Mr. Arkell visited the Maritime Provinces informally in June.

The General Secretary is recovering from his motor accident sufficiently to sit up in bed and has been able to walk across his room with assistance. It is not expected that he will be able to travel to any extent this winter.

New Members

The following applications for regular membership have been received:

R. W. Ward, Dominion Experimental Farm, Kentville, N.S.

Paul Bertrand, Box 425, Lennoxville, P.Q.

J. F. Parthenais, Department of Agriculture, Sherbrooke, P.Q.

Irénée Gervais, 57 Couvent Street, Sherbrooke, P.Q.

Fred Pothier, Department of Agriculture, Lac Megantic, P.Q.

Henri Pintal, Department of Agriculture, Sherbrooke, P.Q.

J. Robert Marcotte, Department of Agriculture, Sherbrooke, P.Q .

C. Ross Healy, Olivier Building, Sherbrooke, P.Q.

R. M. Pugh, Department of Agriculture, Regina, Sask.

As Others See Us

The September issue of the *Experiment Station Record* published by the Uniited States Department of Agriculture, contains a description of the Eleventh Annual Convention of the C.S.T.A. at Guelph. In addition to outlining the programme the *Record* made the following comments:

"The 1931 convention of the Canadian Society of Technical Agriculturists was the eleventh gathering of a body without precise duplicate in any other country. Organized in 1920, the society has now grown in numbers to a total of nearly 1,300 members, distributed among nine provinces and twenty local branches and representative of all phases of technical agriculture. So large a proportion of the leaders of Dominion agriculture with advanced training along these lines is included in its enrollment that the Society was referred to by its president, Dr. W. T. Macoun, horticulturist of the Dominion Department of Agriculture, as 'a federation of alumni, linking the men from the various colleges throughout Canada into one strong body capable of great things for the advancement of Canadian agriculture'. It is affiliated with the American Association for the Advancement of Science and the British Association and other organizations in Great Britain and elsewhere, but its distinguishing feature lies in its unifying influence and leadership.

"Despite the inclusion of numerous speakers from the United States on the Society's programmes and the notably cordial welcome extended to visitors, it is not unlikely that the proceedings and work of this organization are not as well known in this country as their importance and interest merit. The prevailing policy as to the place of meeting is on a rotational basis between the various sections of Canada, and in not a few cases the conventions are more accessible to workers from some of the neighbouring States than are many of the gatherings upon our own soil. Doubtless a larger number than ordinarily cross the border for the purpose would find the sessions both pleasant and profitable. For many others to whom this is impracticable the official publication of the Society, *Scientific Agriculture*, may be commended as a convenient means of a better acquaintance which cannot fail to be mutually helpful".